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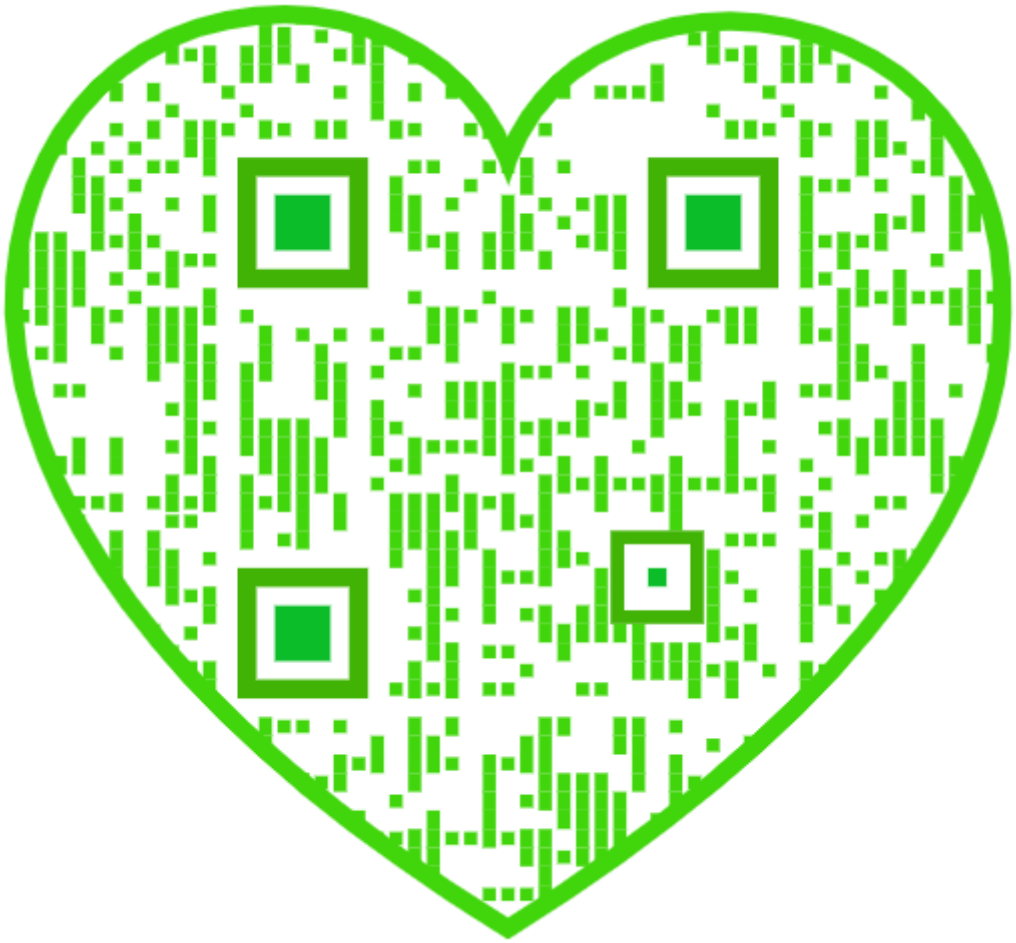

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PREFACE.

THIS hand-book, which forms the first of a series of HANDY-BOOKS FOR HANDICRAFTS, consists chiefly of matter contained in the first edition of "The Metal Turner's Handybook." The book has, however, in many parts, been re-written and additions have been made. Some of the matter and illustrations may be identified as having been taken from various technical periodicals, to which they were originally contributed by me.

The lathe, which is claimed to be the creator of mechanism, is a machine in which all mechanics should be interested. A knowledge of the art of turning finds useful application in all the mechanical arts. Not only is a large proportion of the community employed in these arts, but individuals interest themselves in their practice, as affording pleasurable and profitable recreation. Turnery occupies many workmen, and has special claims on amateurs. If this handybook tends to promote this fascinating and useful art my object will be attained.

THE WOOD TURNER'S HANDYBOOK, which forms a companion volume, I would recommend to the notice of those who are interested in that branch of the Art of Turning.

LONDON, P. N. HASLUCK.

January, 1887.

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THE

METAL TURNER'S HANDYBOOK.

CHAPTER I.

PLAIN LATHES.

LATHES are machines used for shaping material by causing it to revolve while acted upon by a cutting-tool. Turners execute all their work by means of lathes; and on this machine all articles of turnery are fashioned. Lathes vary in size, from the watchmaker's hand-lathe, weighing a few ounces, to the engineer's steam-lathe, weighing several scores of tons. The objects turned vary in size from a great gun, weighing a hundred tons, to a watch-balance staff, weighing but a fraction of a grain. The uses to which lathes are applied are as varied as the dimensions of the machines themselves, and the objects produced on them. Materials of all kinds, applicable to all purposes, are wrought into shape on lathes. The animal, vegetable, and mineral kingdoms each furnish numerous specimens on which the turner operates. Hard ruby and plastic clay are equally susceptive of treatment. Turnery embraces an almost boundless scope; the art is one of the most ancient, and its application has produced some of the most useful appliances of modern civilisation.

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It will be useful to classify the varieties of lathes in common use. Hand-lathes are those driven by hand-power; the ordinary drill-bow being the means most frequently employed. Some hand-lathes are driven by means of a wheel, turned by the left hand, whilst the turner manipulates his turning-tool with his right hand. The turns used by watchmakers is an example of the former; the throw used by clockmakers is an example of the latter. A lathe, driven by other than hand power, which has no slide-rest, is sometimes called a hand-lathe; but the term is in such cases wrongly applied. Probably the fact of the machine being adapted for the use of hand-tools only has suggested the erroneous term. Foot-lathes are those driven by foot-power, generally applied to a treadle, which is attached to a crank-axis carrying a fly-wheel. Any method of applying foot-power for driving the lathe would render "foot-lathe" a correct designation for the machine. Steam-lathes are those driven by steam-power.

To facilitate the production of large numbers of duplicate objects on the lathe, special machines have been built. These lathes often work automatically, and merely require the attention of a lad, who, by shifting a lever or turning a handle as occasion requires, keeps the machine at constant work. The machinery makes no error of judgment; everything is turned to gauge, and every object produced is precisely alike.

The ordinary lathes, which are illustrated in this handbook, have an infinity of uses. No machine is applicable to such a wide range of diverse work, and in no position is the value of a foot-lathe better appreciated than in a jobbing shop. Large factories that possess an endless variety of special lathes, which will turn one particular article indefinitely, are not independent of the foot-lathe. This machine has to cope with the work for which the special lathes are not adapted. The turner who operates a foot-lathe, and who attempts to develop its

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capabilities, has the means of eclipsing one who tends an automatic machine. The ordinary foot-lathe contains the germ of all these machines, and, with the aid of some temporary appliance, is capable of doing all their work. It is the province of the jobbing turner who works at the foot-lathe to construct such appliances, and do all kinds of miscellaneous work. There are thousands of turners—and their number, under the modern system of division of labour, is daily increasing—who have no idea of the infinite capacity of the machine they use. Those who have spent their career at some special work will probably excel in that particular branch, but if some branch of the art new to them is brought under their notice they may be at a loss how to proceed.

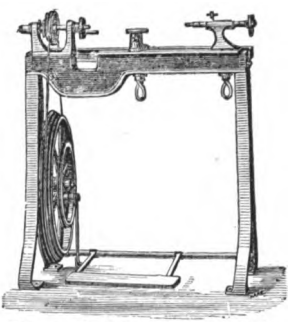

Fig. 1. TANGYES' AMATEUR'S GAP-BED LATHE.

Plain lathes, by which term those that have no gearing or sliding arrangements may be distinguished, shall receive attention first. The lathes illustrated and described have been selected for the purpose of affording varieties for contrast. Each one has some peculiarities that claim for it special notice. Those readers who contemplate purchasing a lathe may advantageously study the peculiarities of varieties illustrated, and so decide on the machine best suited to the work which will be wanted from it. Perhaps the most important item to the majority of intending purchasers is the price, and this has consequently been given in every possible case. A low price must not be taken as a criterion of cheapness. Some tools are utterly useless, and consequently dear at any price.

Fig. 1 shows Tangyes' amateur's lathe; bed, two feet six

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inches long; height of centres, three-and-a-half inches; price £5 5s.; gut-band, 5s. extra; tool-tray, 4s. extra; slide-rest, £4 10s. extra. The fly-wheel is fitted on a stud, which may be adjusted in height to suit the band. The headstock is cast

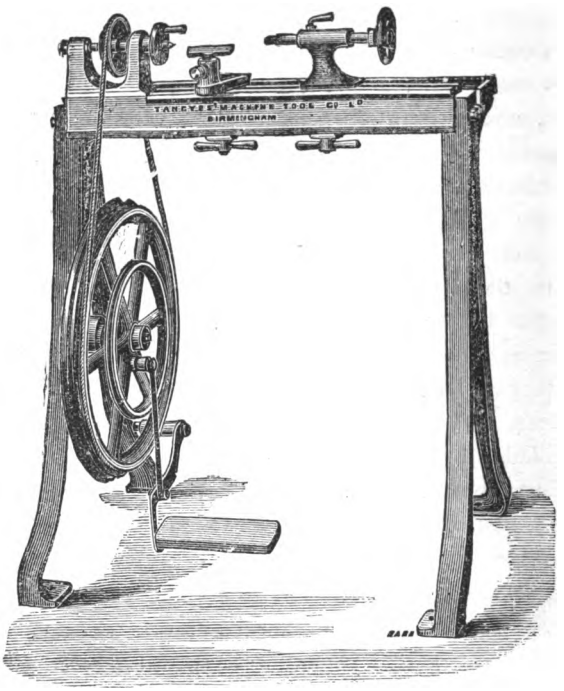

Fig. 2. TANGYES' AMATEUR'S LATHE.

solid with the bed in this lathe; this method obviates the necessity of fitting the headstock to the bed. The bed has a small gap to allow discs of larger diameter than seven inches to be turned.

Fig. 2 is a lathe also made by Tangyes, and which is very similar to the one last described. The dimensions are the same; the price is £5 15s., the bed having no gap. The

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headstock is cast solid with the bed. The fly-wheel runs on a stud fixed to the left-hand standard, and the crank is itself hinged in the same way.

Fig. 3 shows a lathe made by Mr. H. Milnes in various sizes. Three-and-a-half inch centres, with bed three feet six

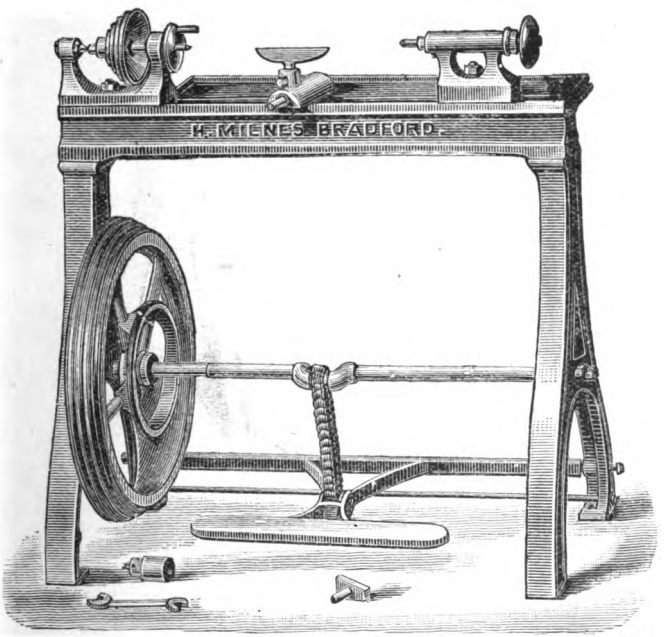

Fig. 3. MILNES' FOUR-AND-A-HALF INCH LATHE.

inches long, price £8 10*s.*; six inch centres, with bed six feet long, price £15 10*s.* The planed iron bed is mounted on strong iron standards. The mandrel has a conical neck of hardened steel running in a hardened steel collar. The adjustable tail-pin is also hard steel. The cylinder poppet is actuated by a steel screw, and has a hard steel centre point. The wrought iron crank has hardened steel ends running on hard steel

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centres. The fly-wheel is balanced, and the crank has an anti-friction motion consisting of an endless chain-band. Three chucks, cone-centres, screw-key, spanner, &c., are included. The workmanship may be judged from the comments on

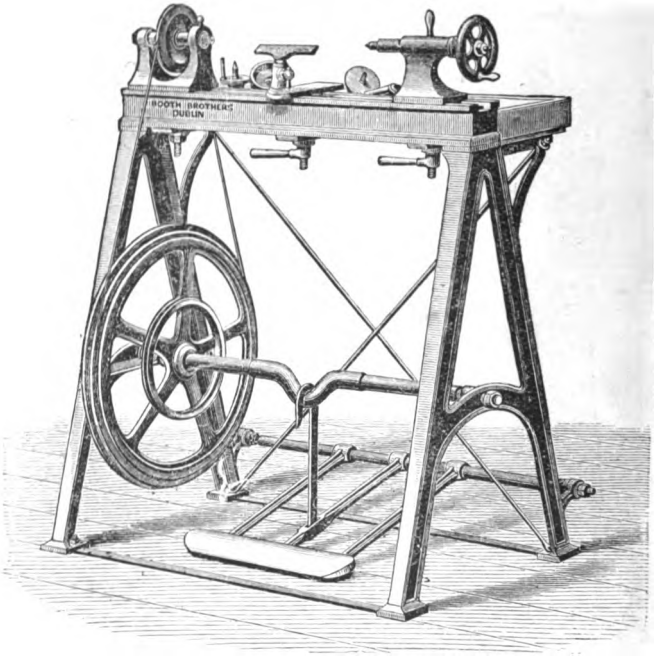

Fig. 4. BOOTH'S FOUR-INCH LATHE.

Milnes' back-gear, screw-cutting, gap-bed lathe, which is illustrated on a subsequent page.

Fig. 4 shows a plain lathe made by Messrs. Booth Bros. Bed, three feet long; height of centres, four inches; weight, about two cwt.; price £12. Four chucks included. The mandrel is steel, running in a conical collar of hard steel. The hand-rest is fitted with three Ts of various sizes. The driving wheel has three grooves on the rim, and one slow-speed

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groove, as shown. The cast-iron standards are braced diagonally by iron rods at the back, the front has a bar bolted to the feet. The machine is delivered with gut-band, wooden tool-tray, &c., complete; the frame work japanned in two colours. A lathe precisely similar in dimensions, but plainly finished and painted, is priced at £9.

The upper part of a very good plain machine recently constructed by the Britannia Company is shown at Fig. 5. It

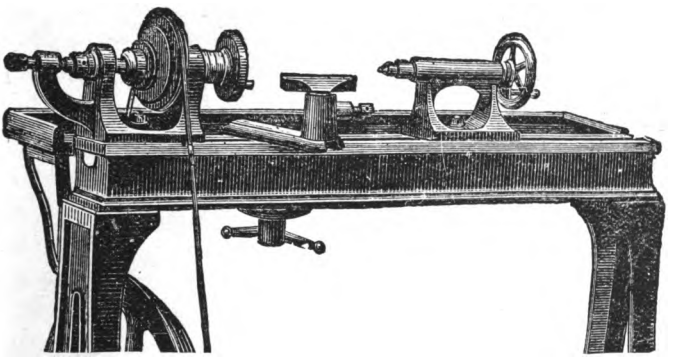

Fig. 5. BRITANNIA COMPANY'S IMPROVED LATHE.

has a three-feet double flat planed iron bed, mounted on strong cast-iron standards. Various heights of centre are made, the price increasing with the dimensions. Three-and-a-half inch centre costs £8, and every extra half inch adds 10*s.* to the price, up to five-inch centre, which costs £9 10*s.* An additional six inches to the length of the bed adds 10*s.* Back-gear adds from £2 to £3 to the price, according to the size. A gap-bed, with the bridge-piece fitted, costs £1 extra. A large and a small face-plate, two Ts, centre-points, spanners, &c., are included. The poppet is fitted with a square-threaded steel screw, which actuates the cylinder. The mandrel is cast steel, with conical bearings. Lock nuts are fitted on the tail end, to take up wear, and an adjusting screw

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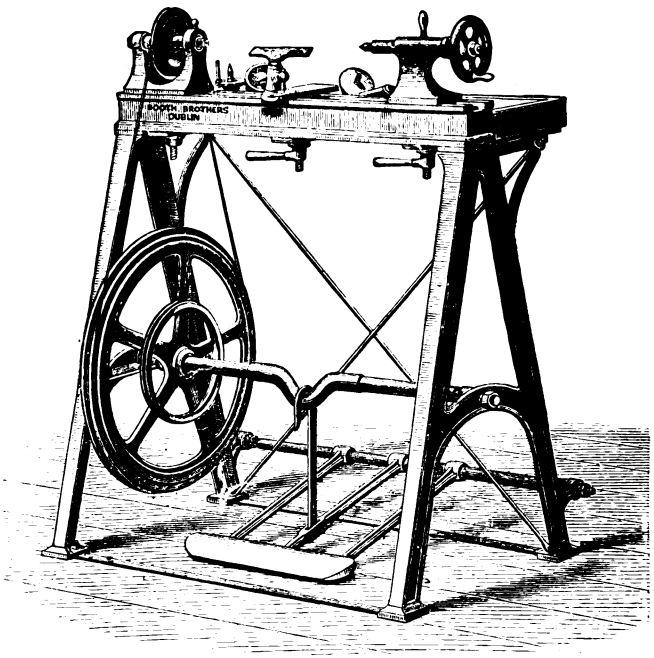
centres. The fly-wheel is balanced, and the crank has an anti-friction motion consisting of an endless chain-band. Three chucks, cone-centres, screw-key, spanner, &c., are included. The workmanship may be judged from the comments on



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ings are split to allow of their being tightened as they wear. Two cone-centres, a fork-centre, a face-plate, and three Ts are supplied with the lathe. The screw in the poppet is sufficiently long to drive the centre-point out when the barrel is drawn back to its fullest extent. The treadle is jointed, so that it will not injure the feet of the workman, should he happen incautiously to get them under the foot-board. Back-gearing to the same lathe costs £3 extra; and a suitable slide-rest, as shown on a subsequent page, costs £2 15*s*.

The scope of this handbook is limited to the application of the foot-lathe to turning metal. Much that is said of this machine is equally applicable to both hand and steam lathes, and the practice of turning metal is, in its essentials, applicable to other substances. The information may, therefore, be adapted to other machines and other materials. Foot-lathes have a wider field of use than either of the other classes. Hand-lathes, which, a generation ago, were considered necessary for producing the most delicate turnery, have been superseded to a great extent by foot-lathes, these being now used for the manufacture of fine watchwork. Steam-lathes involve the use of costly driving-power, and for this reason their use is debarred from workers in a small way of business.

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CHAPTER II.

GEARED LATHES.

BACK-GEAR lathes are constructed with an arrangement of wheels which give a slower speed to the mandrel, and correspondingly greater power over the work. Back-gear usually consists of a wheel and pinion on the mandrel, and a similar wheel and pinion on a shaft fitted in bearings parallel to the mandrel. The driving-pulley is fixed to the pinion; but both revolve freely on the mandrel, the wheel being keyed to the mandrel. The other wheel and pinion are both fixed to the shaft, which forms their axis. When in gear for slow speed, the pinion, on the pulley driven from the fly-wheel, drives the wheel on the shaft; the pinion on the same shaft in turn drives the wheel keyed to the mandrel. The reduction in the speed obtained by this gearing will depend on the relative proportion of the several wheels and pinions. Wheels having sixty and pinions having twenty teeth are frequently used, giving a reduction of one-ninth. This is about the usual ratio in foot-lathes, but the reduction is excessive and causes a very big difference between the fastest speed of the back-gearing and the slowest speed of the ordinary arrangement. The back-gear headstock is used as a single speed pulley by throwing the back shaft out of gear and attaching the wheel on the mandrel to the pulley behind it by means of a sliding-bolt.

Slow motion bands serve the purpose of back-gear for very small lathes. A small pulley on the crank shaft affords suffi-

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cient power for treating work that can be mounted on a small lathe. The constant jarring and noise accompanying the use of gearing is obviated, and smoother work, at a less expenditure of power in friction, is produced by band-gear. The employment of back-gear is a practice rather to be deprecated, as introducing more work, more friction, and an additional

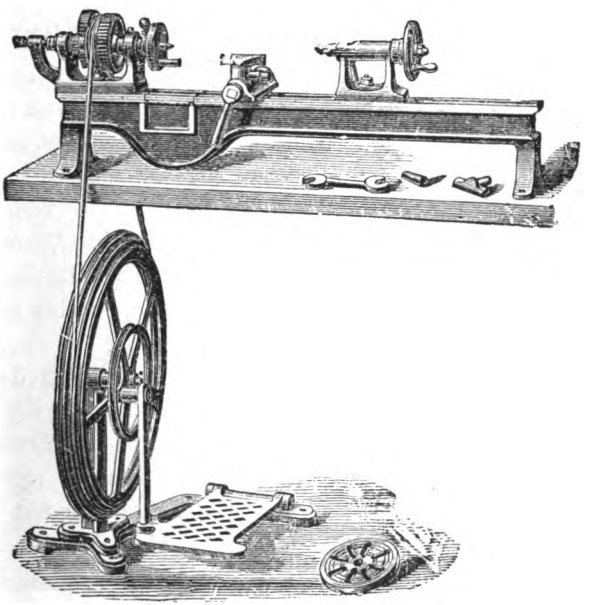

Fig. 7. BACK-GEARED BENCH-LATHE.

source of error into the machine. Larger pulleys on the mandrel, and smaller pulleys on the driving-shaft, would in many cases answer all the purpose of gear-wheels, with the advantage of being less costly and working smoother.

A small back-geared bench lathe is shown at Fig. 7. This lathe is made by the Britannia Company. It is intended to fix on any ordinary bench, the wheel being fixed to the floor be-

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neath. The height of centres is three inches; the bed is thirty inches long. The back-gear bench lathe, as shown with gap and bridge-piece, complete, is £4 10*s*. A plain bed, without gap, is 10*s*. less. The foot-wheel, twenty inches diameter with four speeds, fitted to a pedestal frame with treadle, costs £1 10*s*.

The illustration, Fig. 8, is a lathe very similar to the one shown at Fig. 1. It has back-gear and slide-rest additional. The gap-bed is two feet six inches long, the height of centres three-and-a-half inches, price £7 5*s*., slide-rest £4 10*s*. extra, gut-band and hooks 5*s*. extra. Tangyes are the makers. The fly-wheel is adjustable vertically for tightening the band, and in most respects the general description of Fig. 1 is applicable to the above lathe.

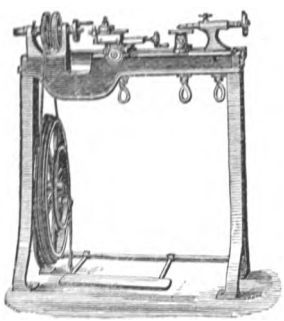

Fig. 8. TANGYES' AMATEUR'S BACK-GEAR LATHE.

A substantially constructed well-finished lathe is shown at Fig. 11. It is a four-and-a-half inch centre; the bed shown is three feet six inches long, but a four-feet bed would be in better proportion. The gear-wheels are machine cut. The mandrel is *hardened* steel running in a *hardened* steel collar. The crank is wrought-iron, plugged with steel centres, which are hardened; the fly-wheel is balanced, and has V grooves for gut-band. The compound slide-rest has the bottom slide fitted at right angles to the bed; the upper slide swivels, and is graduated and indexed for turning any desired degree of taper. Driver-chuck, face-plate, drill-chuck, cone-centres, prong-chuck, bench-board, and screw-keys are included. The price of the complete lathe as shown, but with a four-feet bed, is £15 10*s*., the slide-rest costing £4

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of that money. A gap-bed costs 17*s.* 6*d.* extra; a gun-metal division-plate and spring-stop 17*s.* extra. Lathes of the same pattern are made in various sizes, from three-and-a-half inch centre and three feet six inch bed, to seven-inch centre and seven-feet bed. The former costs £9 10*s.*; the latter £22,

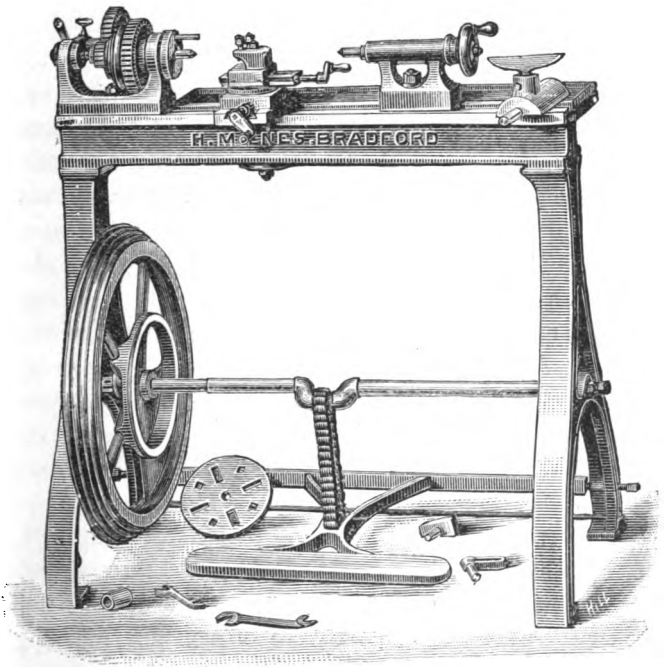

Fig. 9. DOUBLE-GEARED FOOT LATHE.

without slide-rests, which cost £3 10*s.* and £7 respectively. Gap-beds fitted with bridge-piece add 12*s.* to the former, and £1 10*s.* to the latter lathe. The excellence of the workmanship of Mr. Milnes' lathes is mentioned elsewhere in this handbook.

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CHAPTER III.

SCREW-CUTTING LATHES.

SCREW-CUTTING LATHES are those which, by an arrangement of wheels, receiving motion from the mandrel and conveying it to the leading-screw, move the slide-rest along the lathe-bed at a uniform rate, so that a tool fixed in the rest will cut a regular spiral on the surface of a cylinder revolving between the centres. By arranging the wheels which transmit the motion from the mandrel to the screw in relative proportions, the rate or pitch of the thread cut on the work may be coarse or fine to any degree within the compass of the wheels available; these are called change-wheels, twenty-two usually constituting a set.

The leading-screw itself revolves in bearings attached to the bed, sometimes inside, but generally on the near side of the bed; the end towards the mandrel projects, and is made to take the change-wheels. A slotted arm, called the wheel-plate, swinging round the screw, carries one or more studs, on which the change-wheels also fit, the piece of mandrel projecting at the tail end bring similarly shaped. Thus a wheel on the leading-screw, another on the stud, and another on the mandrel make a combination producing an effect proportionate to their relative diameters. The slide-rest is fitted with a clutch-gearing into the leading-screw and forming a nut, which may be detached instantly. A screw-cutting lathe not only affords the means of cutting threads of any rate and diameter perfectly true, but it is also available for working as a self-acting machine

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when turning plain cylinders, the rate of screw then being cut amounting to nothing more than a regular feed.

The principles of screws and screw-cutting on self-acting lathes are not fully discussed here. The whole subject is fully treated upon in "Screw Threads," a small book in which several rules for calculation of wheels are fully explained and many tables are given. It is a complete guide, and forms a useful waistcoat-pocket companion for anyone finding any difficulty in the management of screw-cutting lathes.

A small lathe, particularly suited to the requirements of amateurs and small engineers, is shown at Fig. 10. It is made by the Britannia Company, and having carefully inspected the machine, I am able to speak with confidence of its merits. The design and workmanship of the lathe are exceedingly good, and it is quite unusual to find a cheap machine so carefully contrived and well made. The general run of light engineering work is quite within the capacity of this lathe, and it is well worth the notice of anyone contemplating the purchase of such a machine. The price is £15 15*s*. The same lathe fitted with overhead gear is shown at Fig 16.

The general appearance of the lathe may be inferred from the illustration. It has back-gear, self-acting screw-cutting motion, a set of twenty-two change-wheels, and a rack-and-pinion for quick return motion. The height of centres is three inches, the bed is thirty or thirty-six inches long, provided with a gap-piece three inches wide; by removing this a disc ten-and-a-half inches in diameter may be turned, the back-gear affording ample power to deal with work of that comparatively large diameter. The greatest distance between the centres is nineteen inches, so that any rods not exceeding that length may be turned. Strong iron standards support a walnut top, which has a convenient drawer, as shown, to contain tools, &c. The lathe-bed rests on short legs, the lugs to form bearings for

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the leading-screw being cast solid with the bed. The screw is accurately cut to quarter-inch pitch. The change-wheels fit on studs in the usual manner; there is a reversing motion to

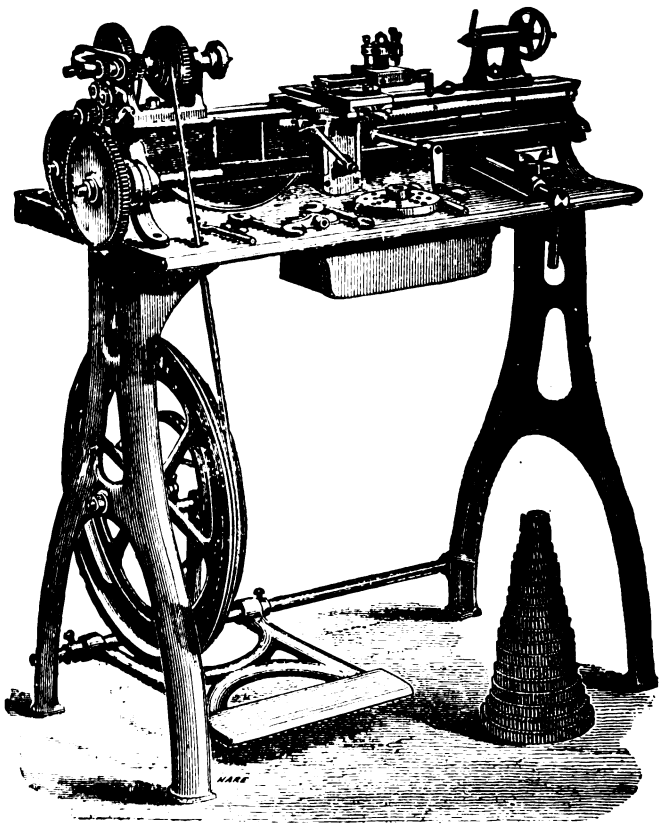

Fig. 10. BRITANNIA COMPANY'S SMALL LATHE.

cause the slide-rest to travel from right to left, or left to right, alternately, without stopping the lathe. Screws, either right or left handed, having from one to sixty threads per inch, may be cut. The steel mandrel has coned bearings at both ends, with

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a screw tail-pin to prevent jambing when boring. The back-gear wheels are put in and out of action by moving their spindle longitudinally. The pulley has three grooves; the driving-wheel having a corresponding series, the largest

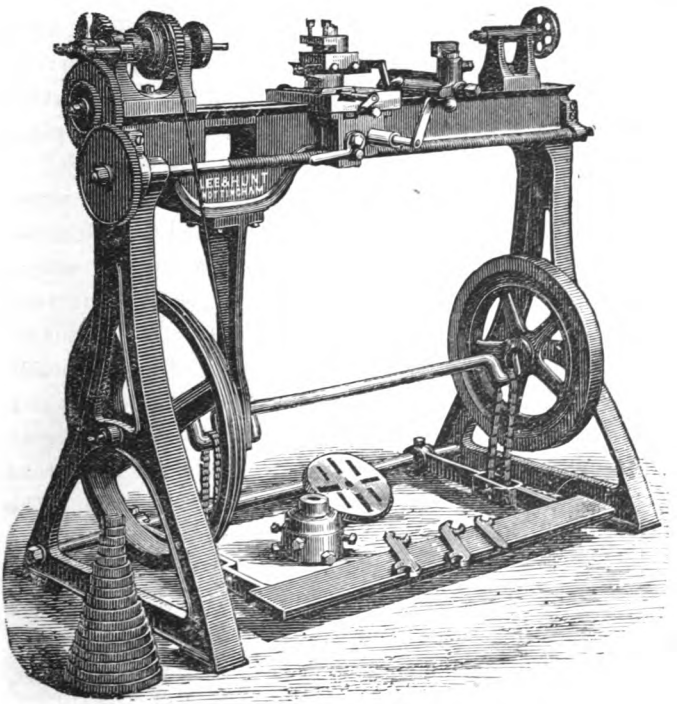

Fig. 11. LEE AND HUNT'S LATHE.

groove being twenty inches in diameter, and also one small groove for slow motion without back gear. The fly-wheel is proportionately heavy, and revolves on a stud fixed in the standard. The bed is under-cut dovetail fashion to take the saddle of the slide-rest. The slide-rest is, of course, compound, with the angular motion of the top slide graduated to 50° on

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either side for turning cones. The clutch or split-nut of the leading-screw is gun-metal, and split in halves, which are separated and closed by means of the lever-handle shown. The tool-holder on the slide-rest swivels round entirely, so that tools may be set at any angle. The poppet head has a steel barrel, actuated by a steel square-threaded screw, fitted with a turned hand-wheel. The clamping handle is to the rear, out of the way. The lathe is sent out in complete working order, provided with hand-rest and T, face-plate, catch-plate, cone-centres, spanners, &c.

Messrs. Lee and Hunt's four-and-a-half inch centre screw-cutting lathe, with back-gear, gap-bed, and double-throw crank, is shown at Fig. 11. The complete machine weighs about five cwt., and the price, with four-feet bed, is £21 10*s.*; extra length of bed costs 15*s.* per foot. Some of the dimensions are as follows:—Bed, five-and-a-quarter inches broad, four-and-a-quarter inches deep; gap, five inches wide, four-and-a-quarter deep; leading-screw, one inch and one-sixteenth diameter, one quarter inch pitch; gear-wheels, one inch broad on the teeth, which are five-sixteenths of an inch pitch. The driving-wheel and pulley have three speeds—for gut, one-quarter inch diameter, or for a strap, three-quarter inch wide. Anti-friction chains and rollers are used to connect the treadle with the crank-shaft. This is supported near the driving-wheel on anti-friction rollers carried by the bracket, shown in the illustration, suspended from the bed. This bearing, added to the usual centre-screws, prevents any tendency to vibration. The fly-wheel is weighted, so that the treadle rests in the correct position for starting the lathe; the crank-shaft also carries an additional heavy fly-wheel at the right-hand end. The compound slide-rest is arranged to swivel for conical turning; the saddle has a quick return motion. The cast steel mandrel runs in phosphor-bronze bearings. In-

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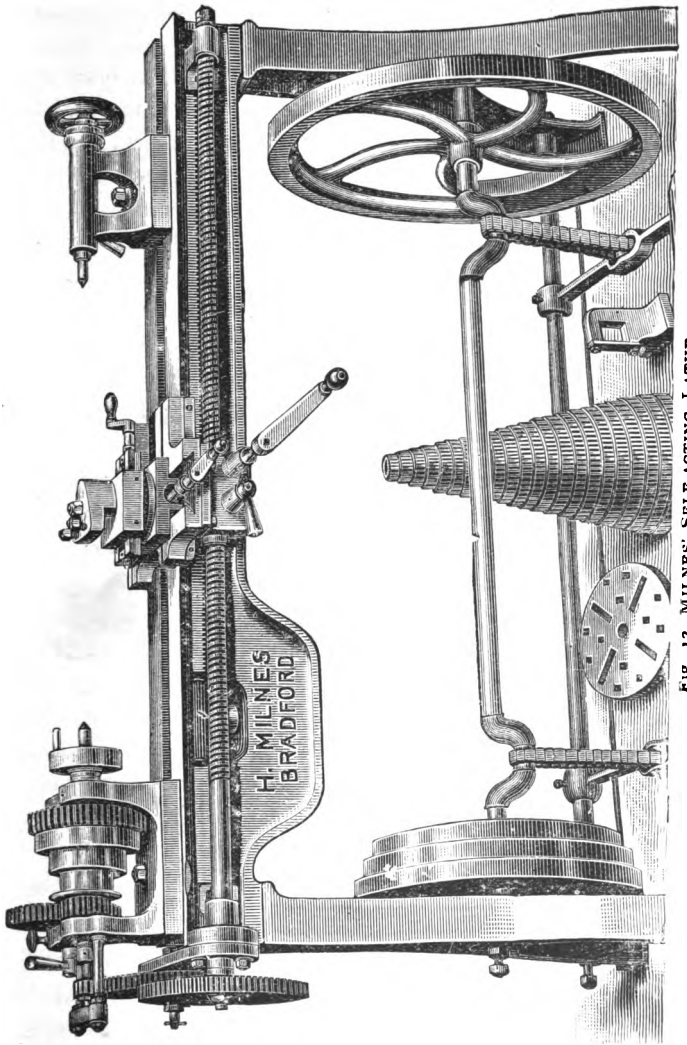

FIG. 12. MILNES' SELF-ACTING LATHE.

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cluded with the lathe are a back-stay, face-plate, catch-plate, bell chuck, hand-rest, and two Ts and a full set of twenty two change wheels.

The large illustration, Fig. 12, shows an excellent machine made by Mr. H. Milnes. It is five-inch centre, the bed is five feet long, the total weight a trifle under eight cwt., and the price is £26. The illustration, being cut down to suit the size of the page, does not show the foot-board of the treadle; the anti-friction rollers are, however, shown. The lathe takes in three feet between centres; it swings seven-and-three-quarter inches over the carriage, and nineteen inches in the gap. The gear wheels in the headstock are machine cut, the back spindle is thrown out of gear by eccentric motion. The mandrel is *hardened* steel, running in *hardened* steel bushes, the bearings being accurately ground. The compound slide-rest is divided angularly for turning cones; there is a rack-and-pinion for quick return of the saddle. The crank is of wrought-iron, with double throw; the fly-wheel weighs more than one cwt., and is balanced. The cone pulley is made to take a strap as shown, or a gut-band, if preferred. All the screws are made of steel, accurately cut to Whitworth's standard pitches. A gap-piece is, of course, fitted to the bed. A travelling back-stay, shown at the lower part of the illustration, fixes to the slide-rest for turning slender work. The saddle of the slide-rest has T slots, so that work may be bolted to it. A full set of twenty-two change-wheels, and an extra stud for cutting left-handed threads are supplied; a face-plate, catch-plate, hand-rest and three Ts, cone-centres, spanners, and bench-board are also included in the price.

I have had a lathe of the above description in use for some years and found it to be an excellent tool. The design is good, the workmanship much above the average of even much higher priced machines, and the price, considering the quality,

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is exceedingly low. If the same remarks are applicable to other work produced by Mr. Milnes, intending purchasers would serve their own ends by negotiating with him for such lathes as he makes, several of which are illustrated in this handbook.

An American screw-cutting lathe, for amateurs, is shown at

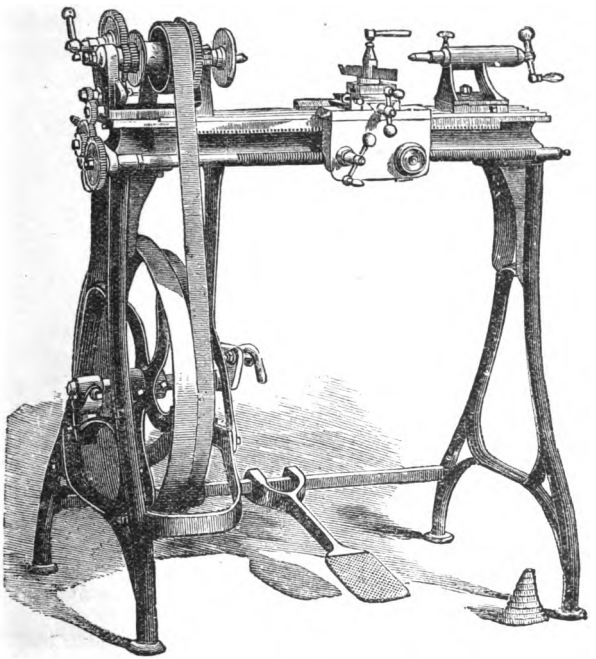

Fig. 13. AMERICAN SCREW-CUTTING LATHE.

Fig. 13. It has four-and-a-half inch centres, a three-feet bed, back-geared headstock, reversing motion for the screw-cutting gear; the poppet head can be set over for turning taper. The fly-wheel is twenty-one-and-a-half inches in diameter, and balanced. It weighs about sixty pounds; the entire machine weighs about three hundred pounds. Work eighteen inches

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long is admitted between the centres, and a diameter of five-and-three-quarter inches will swing over the saddle. The mandrel is bored through with a hole three-eighths-of-an-inch diameter. The change-wheels supplied with these American lathes are all machine cut, that is to say, the teeth are cut from the solid metal, instead of being cast, as in the English wheels. The teeth are much finer, the set supplied embracing a range of threads from five to forty-eight per inch. The price of the

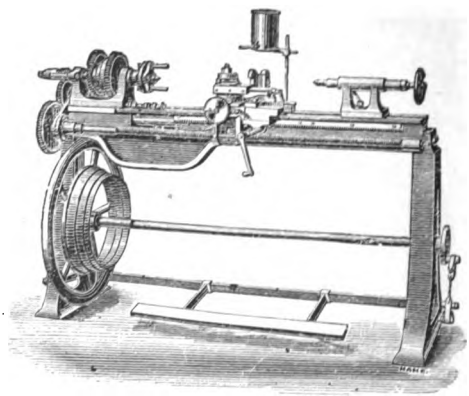

Fig. 14. TANGYES' ENGINEERS' LATHE.

complete machine is £27 10*s*. An additional twelve inches of bed, which increases the weight by about twenty-five pounds, adds £1 to the cost. A wide strap is used to transmit motion from the fly-wheel to the mandrel, and only two speeds are admissible.

Tangyes' engineers' slide and screw-cutting foot-lathe is shown at Fig. 14. The lathe is made in three sizes. Heights of centres, five, six and seven inches; length of beds, five, six and eight feet. Prices, £36, £48, and £60; screw cutting, extra, £4, £6, and £8; bridge-gap, £2 extra for the two small sizes, and £3 for the large. The specification of

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Fig. 20 applies to this lathe in all applicable particulars, the same chucks and other appliances are supplied with both.

A five-inch centre, five-feet bed lathe is shown at Fig. 15

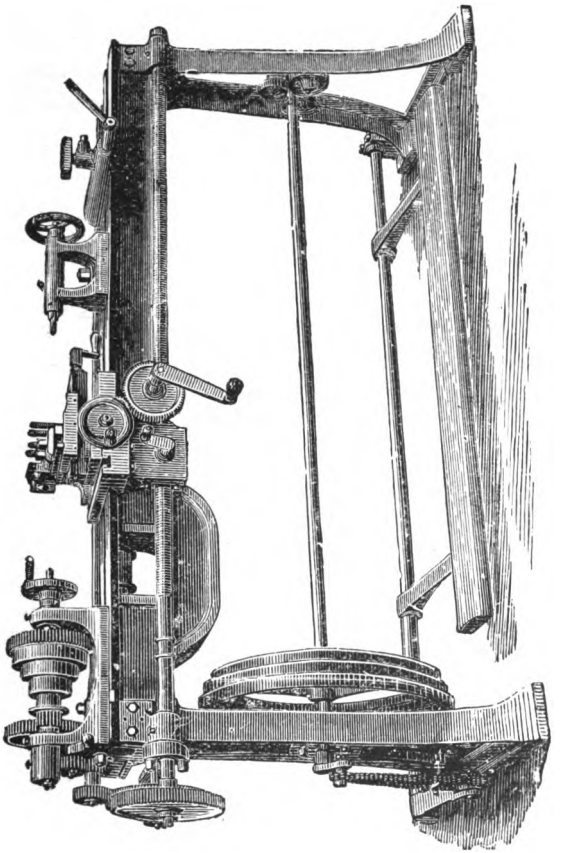

Fig. 15. SELF-ACTING SLIDING AND SURFACING LATHE.

The machine is made by Messrs. Cunliffe and Croom, who style it well adapted for jobbing and repairing purposes, and invaluable to amateurs. The price of the lathe shown is £46 10*s.*; packing and packing-case is charged at five per

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cent. on this amount, and carriage is also extra. Additional length of bed is £1 10s. per foot, and if the wheel and pulley are grooved for gut-band, 5s. extra is charged. A lathe, six-inch centres and six-feet bed, is priced at £57 15s. The slide-rest is fitted with self-acting surfacing motion, worked by the leading-screw. The crank shaft runs on anti-friction wheels. The mandrel has hardened steel cone-bearings and bushes, or parallel bearings running in brass.

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CHAPTER IV.

OVERHEAD GEARING.

OVERHEAD GEARING is a valuable addition to any lathe, and at once opens a fresh field for work. The importance of overhead gearing is not recognised at its just worth by those who have not had the advantage of using it. Revolving tools, driven from the overhead gear, afford a means of doing, expeditiously and well, much work that could not be done otherwise. In a subsequent chapter various cutters are illustrated and described, and also the apparatus in which they are mounted for driving with overhead gear. A plain drilling-spindle will afford the means of doing much, and a vertical cutter-frame enlarges the sphere of action. It would be scarcely possible to enumerate the variety of work that can be done with the aid of these appliances used with overhead gear. Shaping prismatic pieces of all descriptions, cutting slots, grooving taps, squaring the flats of bolt-heads, drilling holes, as in division-plates, are some of the uses to which they may be put.

Overhead gearing is modified to almost any extent. Of the many plans adopted, local peculiarities most frequently influence their suitability. Sometimes the wall or ceiling happens to be in handy position for fixing the apparatus. In such cases it is always wise to make every possible use of such staunch supporters. When a lathe is fitted up independent of such extraneous supports, uprights have to be attached to the framework to carry the overhead. The specimens of over-

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head gearing that are shown in this handbook are fixed to and form part of the lathe itself.

Fig. 16 shows the lathe illustrated on page 16 fitted with overhead gear.

The most simple and inexpensive way to fit up a useful

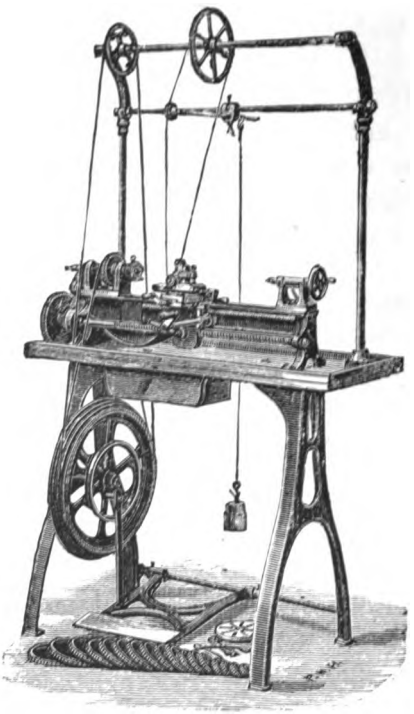

Fig. 16. LATHE WITH OVERHEAD GEARING.

overhead gear is probably the following:—Procure a bar of round iron the same length as the lathe bed, the diameter of which may be five-eighths of an inch if less than three feet six inches long; and three-quarters of an inch if more than that length. Fix this bar vertically above and parallel with the

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lathe centres, at such a height that it may be easily reached by the workman. From six feet to six feet six inches from the ground will be found convenient to men of ordinary stature. The iron bar must be fixed securely at both ends, so that it can neither rotate nor move longitudinally. Two pairs of

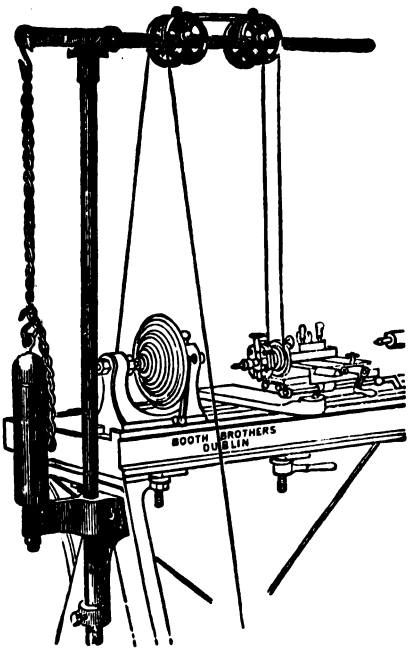

Fig. 17. BOOTHS SWING BAR OVERHEAD GEAR.

grooved pulleys are fitted so that they may be slid along the bar to any desired position, and there fixed. These pulleys give the means of directing a driving-band, from the lathe fly-wheel, to any rotating tool fixed in the slide-rest. A glance at Messrs. Booth Bros.' overhead gear will show the method plainly.

The illustration, Fig. 17, shows a complete swing-bar over-

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head gear, made by Messrs. Booth Bros. This attachment, complete in itself, is sold for £5. It weighs about twenty-eight pounds. It may be fixed to any lathe in the manner shown, that is, bolted to the standard. A bracket-piece is provided for this purpose, the upright rod fits it, and is secured by a bolt, so that it may be easily removed if required. The top end of the upright rod carries a piece provided with a bearing for the vertical bar, which swings free on the joint shown. This bar carries two pairs of grooved pulleys, which may be shifted to any position along the bar. The left-hand end has a hole by which a chain is attached, and the cylindrical tube at the bottom, fixed to the bracket-piece on the standard, contains a spiral spring, the tension of which may be regulated by adjusting the length of the chain. This spring tension dispenses with the use of loose weights.

In use this overhead gear is placed with the horizontal bar vertically over the lathe bed. The pair of pulleys on the left are placed just above the fly-wheel, so that the band will run on and off properly. The pulleys on the right are then placed above the pulley of the instrument in the slide-rest. The driving band is then put around the fly-wheel, and over the pulleys to the instrument. The tension is adjusted by means of the chain on the left, which is linked up to suit. It will be noticed that the bar is capable of being swung backwards and forwards on the axis of the upright rod, as well as vertically. For the purpose of driving revolving cutters, a swing bar overhead gear, as here shown, is frequently all that is necessary.

The lathe shown at Fig. 18 is a specialité made by Mr. Hines. It is called the "Officers'" lathe, and is designed to supply the requirements of those who make ornamental turning a special recreation. Overhead gearing is a noticeable feature in this lathe. The band from the fly-wheel drives a

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shaft running vertically above and parallel with the lathe

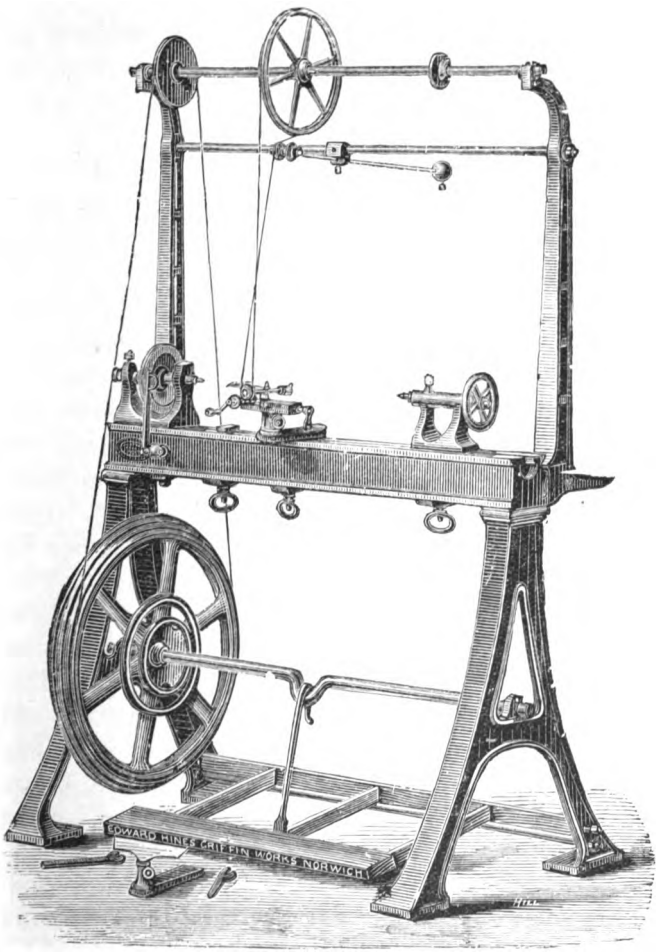

Fig. 18. OFFICERS' LATHE.

centres. This shaft carries pulleys—one large and one small are shown—from these a band is led to any revolving cutter

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apparatus that may be in the slide-rest. The pulleys slide along to any desired position on the shaft, this having a key-groove the entire length. The stay-bar connecting the tops of the uprights carries a balanced lever provided with guide-pulleys, which serve to guide the band and keep it taut.

The "Officers'" lathe is made in different sizes at various prices, from £26 10s. to £33 complete. The former has a three-feet bed and four-inch centres; the latter a four-feet bed and five-inch centres. The following is the specification of these lathes:—Headstock has hardened steel mandrel; cast-iron four speed, V grooved cone-pulley; engraved division plate, having four circles of holes, viz., 180, 144, 120, 112; and spring index-peg. The poppet has a steel cylinder and steel square-threaded screw, polished hand-wheel, and hardened steel-coned centre. The wrought-iron crank-shaft works in metal bearings, provided with efficient dust-covers; the fly-wheel has five grooves. The hand-rest has three Ts. A set of spanners, oil-can, gut-bands, steel-tommy, &c., and a mahogany tool-tray are also included. The turned overhead shaft runs in metal bearings provided with dishes to catch any drips of oil. The pulleys on the shaft are a cone-pulley, corresponding to that on the mandrel—one twelve inches, and one three inches. All parts are manufactured on the duplicating system, ensuring accuracy. The maker says these lathes, though comparatively small, are very compact, and are the result of many years' experience. A feature worthy of imitation is that the bow-nuts and plates of the poppet-head, hand-rest, &c., are made to pass between the cheeks of the bed, so that those apparatus may be lifted entirely off the bed without the trouble of entirely unscrewing the bow-nuts. These lathes, fitted with an ornamental slide-rest and an eccentric cutting-instrument, or even a plain drilling-spindle, are capable

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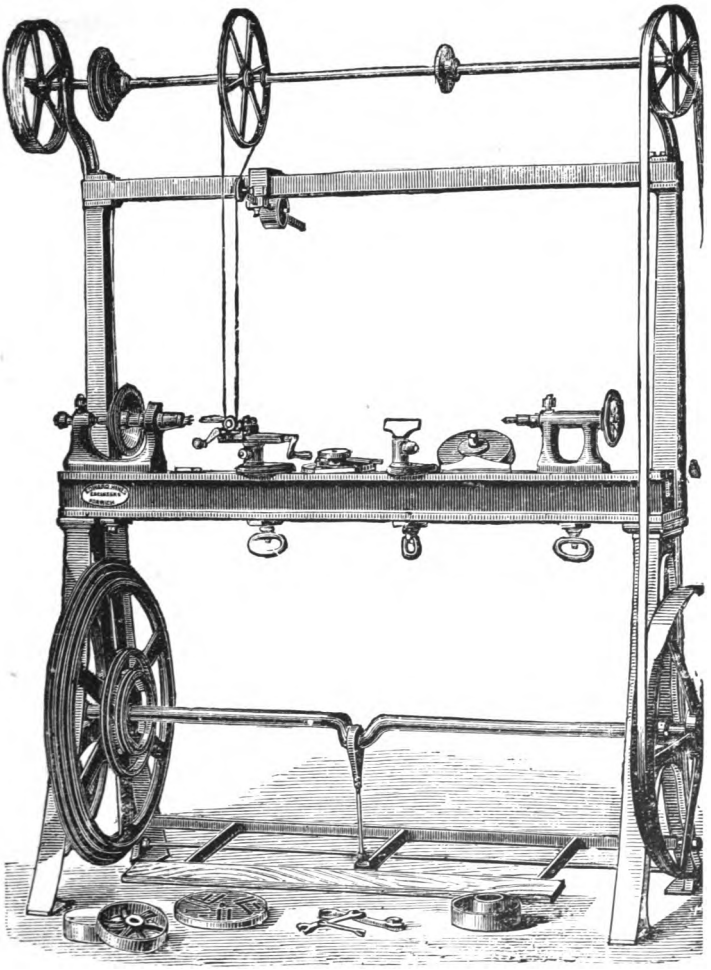

Fig. 19. "CLARENDON" LATHE.

of producing many elegant figures in hard wood, ivory, and light metal.

The "Clarendon" lathe, also made by Mr. Hines, and

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shown at Fig. 19, has many points of similarity to the "Officers'" lathe last described. The illustration shows the chief modifications to be an extra fly-wheel on the right-hand end of the crank-shaft. The overhead shaft is extended beyond the bearings of the uprights, and carries a plain flat pulley on each end. A strap from the right-hand fly-wheel direct to the pulley above communicates motion to the overhead shaft. The uprights are connected near their tops by a strong square bar; this bar carries a balanced tension-arm as described in the "Officers'" lathe. The "Clarendon" costs £3 10s. extra.

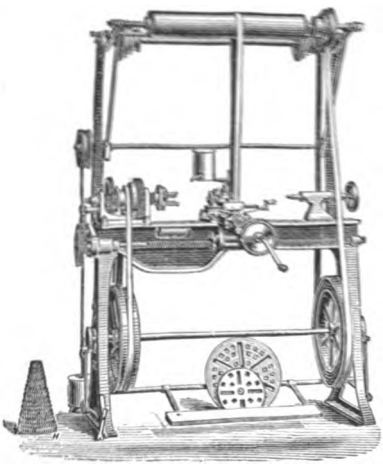

Fig. 20. SCREW-CUTTING LATHE, WITH OVERHEAD GEAR.

A screw-cutting lathe, with overhead gearing, is shown at Fig. 20. This lathe is manufactured by Tangyes in two sizes; four-and-a-half inch centres, with four-feet bed, price £36; or fitted with overhead motion, as shown in Fig. 20, £52 10s.; five-inch centres with five-feet bed, price £42. The overhead gearing is a different arrangement to those that have been already described. The uprights carry a revolving shaft provided with cone-pulleys at each end; one reversed to correspond with that on the mandrel. Parallel to that shaft, and having its bearings in a swinging frame, is another shaft. This has a drum extending the greater part of its length, and is driven by a strap from the first shaft. A strap from the drum drives any [illegible]nce used in the slide-rest, the tension of this strap being

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effected by means of levers fixed to the swing-frame, and weighted to suit requirements. With this running-drum the slide-rest may be traversed along the bed whilst the overhead gear is in use, the strap shifting itself along the drum as the pulley of the machine that it drives is moved. An adaptation of this form of overhead gear has been used for speeding pulleys to cut screws by band-gearing. The system appears to have been successful when properly carried out, but it has had but few advocates.

The lathe illustrated is described as a very superior machine, with planed cast-iron bed, mounted on two standards; double geared headstock, steel mandrel, with hardened neck working in hard conical adjustable bushes; gap in bed, with removable piece accurately fitted; compound slide-rest on saddle arranged for turning conical and for surfacing; improved gun-metal clamp-nut; steel guide-screw whole length of bed; quick withdraw motion; adjustable back-stay; full set of change-wheels; two face-plates—one full size of gap; a Clement's driver-chuck; turned fly-wheel and pulley, and full set of spanners. The smaller size has self-acting surfacing motion. I have had one of these lathes in use for some years. The crank-shaft runs on friction rollers and extends beyond the standards, the treadle being connected at both ends, thereby ensuring extra steadiness. Two fly-wheels are used, one at each end of the crank-shaft.

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CHAPTER V.

SLIDE-RESTS.

SLIDE-RESTS are probably the most useful, and, in fact, form an indispensable adjunct to the metal turner's lathe. Although much work can be done on the lathe by the aid of hand-tools, yet a slide-rest greatly enlarges the capabilities of the machine. A properly-made, securely-fixed slide-rest will hold a tool perfectly rigid, no matter how irregularly the work may act upon it. By the aid of a slide-rest the corners may be turned off a square rod of metal as easily as turning cylindrical rods; with hand-tools the difficulty would be increased in the former case. Work which has a break in the continuity of its cylindrical surface is not easily turned with hand-tools, as may be readily proved by trial. In turning a parallel cylinder by hand-tools considerable care and constant gauging are requisite to guard against cutting too deeply at some part. With a slide-rest there is no need of such care, for, when the tool has been properly adjusted, a perfectly true and parallel cylinder will be produced by simply feeding the tool up to the work.

Slide-rests offer a mechanical hand to hold the turning-tool, and the relative value of mechanical work and hand-work will be appreciated by mechanics. In many cases the latter cannot be dispensed with, but automatic duplicating machinery has superseded hand-work in many processes. Machinery makes no errors of judgment; when an accurate machine is used the product is accurate, everything is turned to gauge as

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predetermined, and every object made is precisely like its fellow. Slide-rests, in the innumerable adaptations of their component parts, are the means employed to regulate most of the automatic lathes.

The advantage of slide-turning over hand-turning will be best appreciated by comparing work done by the two methods. A plain cylindrical rod—say, for instance, a bar of shafting—may be mounted on a lathe fitted with a slide-rest, and turned up perfectly true, parallel and smooth within the limits of the travel of the rest. Suppose the same operation had to be done with hand-tools. Compare the truth, the parallelism, and the smoothness of the bars produced by the two methods. In all cases the comparison will be favourable to the machine work. Thus, we find that the quality of the machine work is better. Then consider the time taken in the two methods; the time necessary to do the work by hand is very much more. The labour—that is to say, skilled labour—is an unnecessary quantity in the case of machine work, whereas only a turner of exemplary skill could successfully accomplish the work by hand. Compare the relative wages of the artificers, the relative quality and quantity of the work they produce, and the advantages will in each case be in favour of machine work.

Various forms of slide-rests are commonly used. The purpose to which it is to be applied generally influences the design of the slide-rest chosen. One that is best adapted for turning heavy metal work is not suited for light ornamental purposes when working on ivory and hard woods. The converse is equally true, but it seldom happens that two slide-rests are used on one lathe. In fact, lathes constructed for heavy work should have a heavy slide-rest, and light lathes ought to be provided with rests that are in proportion. Several slide-rests of various patterns are illustrated in this handbook, and it

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must be left to individual judgment to select the one best suited to the purpose contemplated.

Some of the principal features that are desirable may be enumerated. It is essential for all purposes that slide-rests be perfectly rigid under ordinary usage. The slides should work quite parallel and true with the lathe centres, when the rest is tightened on the bed. There must be a fair range of traverse to the slides, so as to allow a tool to be applied to an average surface of work without the necessity of shifting the entire rest along the lathe-bed. When the rest slides along the bed, as in screw-cutting lathes, the longest possible range of traverse is provided. For ornamental work, with the drilling-instrument, wheel-cutting instrument, or universal cutting-frame in the slide-rest, and the division-plate in use, it is almost necessary, or, at any rate, very convenient, to be able to throw the tool in and out of cut readily, and to quickly replace it accurately to the same setting. For drilling a series of holes, cutting teeth in wheels, and other purposes, the convenience is apparent. A lever handle is useful for this purpose. In plain turning this lever is often very objectionable, as it necessitates the undivided attention of one hand, when both hands are frequently wanted to manipulate other parts.

A slide-rest should be strong enough in all parts, not merely to resist absolute breakage, but to maintain perfect rigidity under the influence of a heavy cut. There are many qualities that influence the stability and inflexibility of a rest. A certain amount of metal is necessary to make a rigid slide-rest, but much more depends on the fashioning of the metal than appears to be generally understood. Good fitting is also requisite for rigidity. A carefully-fitted rest, chaste and elegant in design, will stand more hard wear and tear than half-a-dozen of the badly-fitted, clumsy, heavy tools thrown on the market by makers of inferior engineering appliances.

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The illustration, Fig. 21, shows a slide-rest designed expressly for enabling the production of, with one tool, either delicate work in ivory and hard woods, or the usual heavy metal turning that can be done on a foot-lathe. The tool is made by Mr. Hines, who terms it "the universal compound

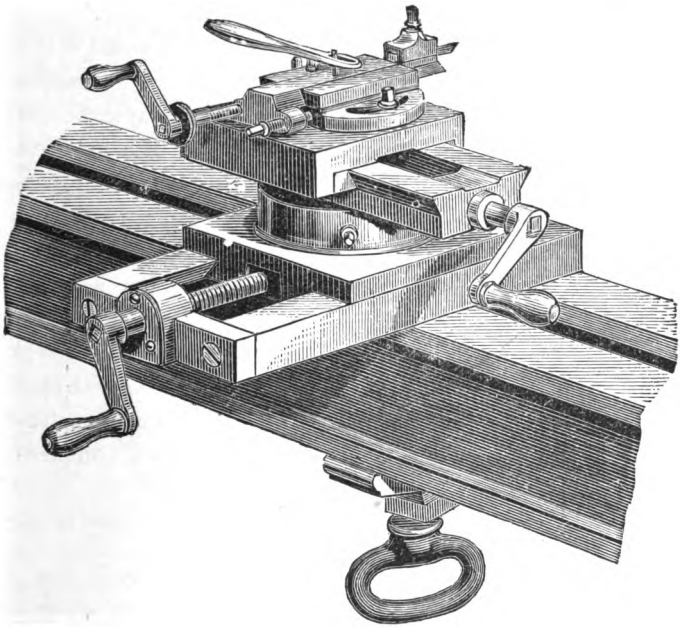

Fig. 21. "UNIVERSAL" SLIDE-REST.

slide-rest." It is shown fixed to the lathe-bed. The upper portion shown in the figure is independent of the other parts of the rest, and may be taken off when not required for ornamental work. This upper portion consists of a carefully-fitted tool-slide, with a receptacle to hold the usual forms of cutting-tools used for working in wood and ivory. It is fitted with a screw by which the slide may be actuated; also with a lever-handle for the same purpose. Stop-screws to regulate the

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depth of cut are also provided. A glance at the "Model" rest, shown on another page of this handbook, may serve to elucidate the construction of this tool-box.

The base-slide is constructed to take the bearing of its saddle on the outer edges, which gives greater firmness to the tool than if the saddle were fitted as the top-slide in this rest. The different ways of fitting the dovetail slides may be noted in the various rests that are subsequently illustrated. The top-saddle generally fits on the inner side of the dovetails, because there is not sufficient space for the projecting web. The top-slide swivels round for turning cones, and the upper portion is replaced by a tool-holder, as shown on some of the other rests, when metal turning is to be done. The above rest, complete, with all the accessories shown, costs from £12 12s. to £15, according to the size, from four to six inch centre. The leading screws are steel, cut with ten threads to the inch.

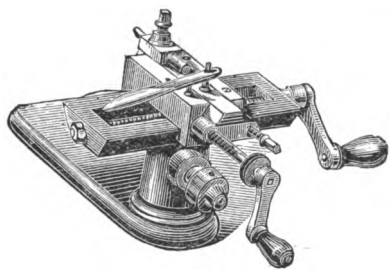

Fig. 22. "MODEL" SLIDE-REST.

The "Model" slide-rest illustrated at Fig. 22, manufactured by Mr. Hines, shows the most simple form in which a slide-rest can be constructed to be an effective tool. The base of this rest is similar to the socket of an ordinary hand-rest; it is held on the lathe-bed by a bolt and bow-nut in the usual way. The main slide, which is the lower one, has a cylindrical stem, which fits into the socket of the base. This stem is in the centre of the slide, midway between the ends. A set-screw tapped into the socket, so that its point impinges against the stem, affords the means of fixing the main-slide at any angle

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with the lathe-centres, and also at any desired height. The length of this main-slide is six inches for a four-inch centre rest, and nine inches for a six-inch centre. The first costs £5; the second £6. The leading-screw that actuates the saddle on the main-slide is steel; it has a square thread, ten threads to the inch. The tool-slide is fitted in a dove-tailed groove in the saddle of the main-slide. A lever-handle is used to actuate this top-slide; the fulcrum fits into holes in the saddle, a slot in the end passing over a pin in the slide. A regulating screw, having twenty threads to the inch, affords the means of advancing the tool gradually. A stop-screw, shown on the left, prevents the tool from going in too far. The surface of the main-slide may be graduated to any scale required. The collars of the leading-screws may be divided; and a line scratched on the slide affords a guide for accurate adjustments. The collar of the main leading-screw divided in ten equal parts would show the hundredth part of an inch. The tool box in this slide-rest is a rectangular mortise, made in a lug cast solid with the top slide, having a capstan-headed clamping-screw tapped through a boss on the top. The little rest above illustrated is an exceedingly handy tool, and will be found extremely useful either for working in ivory or hard wood, or for mathematical instrument making.

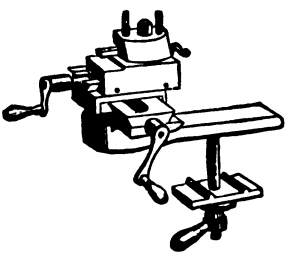

Fig. 23. LOW-PRICED SLIDE-REST.

The slide-rest shown at Fig. 23 is a pattern made by Messrs. Booth Bros., and the size suited for a four-inch lathe costs £5 10*s*. The lower slide of this rest is parallel with the lathe-bed, and it may be fixed at any desired distance from the lathe-centres, according to the diameter of the work being turned.

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This adjustment enables a much shorter slide to serve the purpose of the long one. The top-slide in the rest here shown is only used for setting the tool into cut. The tool is placed near to its required position by sliding the rest on the lathe-bed. When rests, with slides at right angles to the bed, are used, the tool has to be shifted to or from the line of centres by means of the screw. Slide-rests, like Fig. 23, are not to be recommended in preference to the much more solid tools shown by Fig. 21, except when low price is the chief consideration.

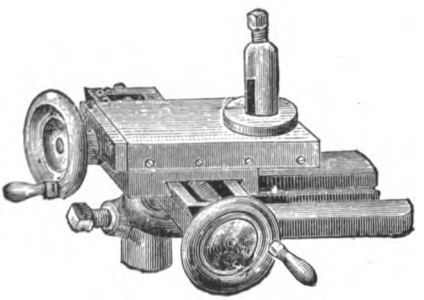

Fig. 24. "EUREKA" SLIDE-REST.

The "Eureka" slide-rest shown at Fig. 24 is an American tool, imported by Messrs. Churchill. The base piece is like a socket of a hand-rest, inverted; it affords the means of placing the tool at any required distance from the lathe-centres. By means of the stem of the rest which fits in the socket, the entire tool may be raised or lowered to suit any height from two to three inch centres. The lower slide will travel three-and-a-half inches, the upper one one-and-three-quarter inches. The slide-rest is furnished with four turning-tools, and costs £1 10s. It can be used for boring or turning, either parallel or taper.

Another American tool imported by Messrs. Churchill, and termed the "Eagle" slide-rest, is shown at Fig. 25. The construction of this tool may be inferred from the illustration. The prices are: for four-inch lathe, having four inches traverse, £2 15s.; for five-inch lathe, having seven inches traverse, £5 10s.

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A sample of the slide-rests made by the Britannia Company is shown at Fig. 26. All sizes, from two-and-a-half inch to eight-inch centre, are made. The prices range from £2 for the former to £8 for the latter size; a six-inch rest costs £6. The rest shown has a swivel tool-holder, which revolves freely in the top-saddle, and the tool is fixed by a single clamp-screw. The large size rests are provided with a stronger tool-holder, having two clamp-screws. The upper slide swivels round to any angle for turning conical work; and the base is graduated and fixed with an index to facilitate the setting. The lower saddle is long, to cover the slide, and so excludes chips and dirt from

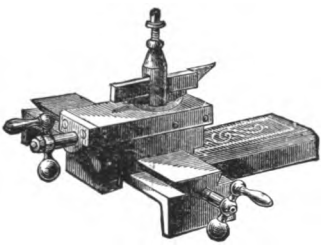

Fig. 25. "EAGLE" SLIDE-REST.

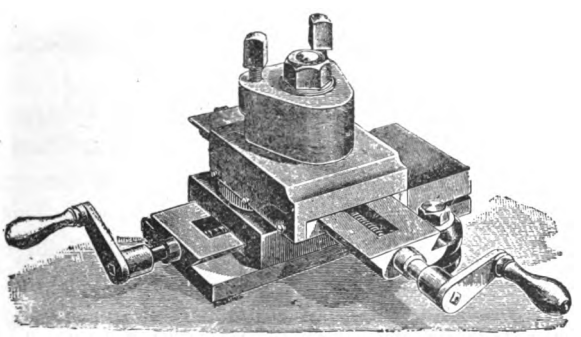

Fig. 26. BRITANNIA COMPANY'S SLIDE-REST.

the screw. The leading-screws are steel, cut with square threads, and work in gun-metal nuts. The handles are horn, fitted to squares on the screws. All the parts are machined to size, and thus the parts of slide-rests of a particular size are interchangeable.

Fig. 27 shows the slide-rests made by Messrs. Cunliffe and

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Croom. They are suited for lathes with either straight or gap beds; in the latter case they are fixed by an eccentric bolt and lever, an ordinary bolt and bow-nut being used on a straight bed. This rest is very similar to that shown at Fig. 28 It is

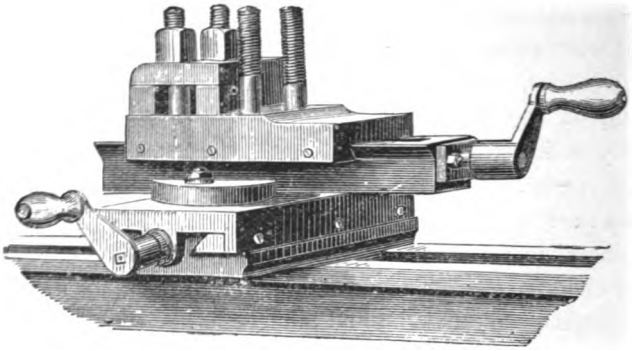

Fig. 27. CUNLIFFE AND CROOM'S SLIDE-REST.

made in sizes from three to twelve inch centres, the prices being £3 10s. for the former and £14 10s. for the latter. A six-inch rest costs £6 10s.

Compound slide-rests, as made by Messrs. Tangyes, are illustrated by Fig. 28. The small size of the illustration does not permit much elaboration in the details, but the general construction may be inferred. This rest is a pattern specially adapted for metal turning, and the design is particularly good. It is unnecessary to draw especial attention to the various peculiarities, as these may be observed by comparison with other rests illustrated in this handbook. The prices of this rest vary with the size; three-and-a-half inch centre costs £4 10s.; six-inch centre, £7 10s.; and twelve-inch centre, £15 15s.; the intermediate sizes being a proportionate price.

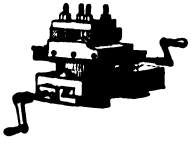

Fig. 28. TANGYES' SLIDE-REST.

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A substantial metal-turner's slide-rest is shown at Fig 29. It is made by Mr. Hines at various prices, according to size and finish; four-inch centre costs from £6 to £8 10*s.*; six-inch centre from £8 to £10 10*s.* The lower saddle rests on its outer edges; the screw has a bearing at one end only. The upper slide swivels on a central pin, and the base may be divided for facilitating the setting of the slide to turn cones to any particular angle. The top-saddle is shown fitted with a

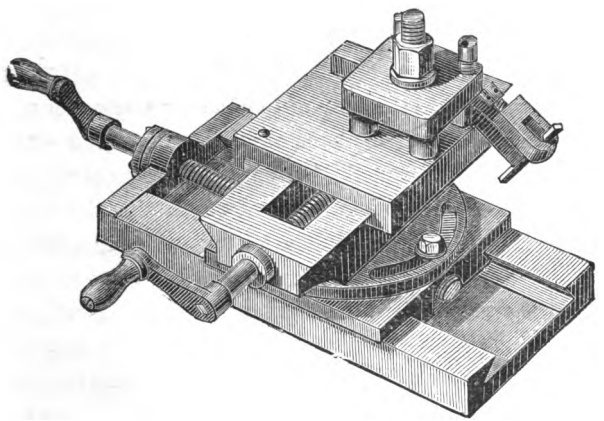

Fig. 29. METAL TURNER'S SLIDE REST.

tool-holder of the most useful form. Those who purchase slide-rests should insist on having tool-holders made as the one illustrated on this rest; it is stronger and more efficient than most others. It turns freely on the central bolt, and has two clamping-screws to fix the tool; as the tool-holder turns freely, the tool may be fixed at any angle. The leading-screws of this slide-rest are steel, square-threaded, cut to Whitworth's pitch. A holding-down bolt and bow-nut, to clamp the rest on the lathe-bed, are included.

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CHAPTER VI.

SCREW-CUTTING WITH SLIDE-RESTS.

THE application of slide-rests to the purpose of cutting screw-threads has been very often attempted, with more or less satisfactory results. The leading-screw of the rest has been made to do the duty of the leading screw of a screw-cutting lathe. Various methods of gearing the screw with the mandrel have been adopted; but gut-bands or toothed wheels appear to be the only practical means of effecting the purpose. A band from the mandrel pulley to the overhead shaft, and another band from this to a pulley on the slide-rest screw, gives a means of speeding the traverse of the tool. Band-gearing appears to be tabooed by popular prejudice, from a prevalent idea that the bands slip, and, consequently, no reliance can be placed on the accuracy of the speeding effected. Experiments show the idea to be erroneous, and the system is well worthy of employment. Toothed-wheels gearing the mandrel with the slide-rest screw are more popular, from the obvious certainty of their action.

An arrangement for utilising the screw of the slide-rest for screw-cutting is adapted to some lathes, and is explained in the following particulars:—The apparatus connects the revolutions of the mandrel with those of the slide-rest by a train of toothed wheels. It is adapted to plain foot-lathes having either back-centre or traversing mandrels, and affords the screw-cutting powers of the ordinary slide or screw-cutting lathe, together with some others. It is, perhaps, the most convenient arrange-

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ment for cutting screws and spirals not exceeding eight or nine inches in length, which length may be said to comprise the whole of the screws required in works executed on the foot-lathe. The slide-lathe is essential for cutting long screws, and for the execution of large and long plain turning. On the other hand, the slide-rest apparatus, precisely the same in principle, may be fairly considered to have certain special advantages. It is more compact, less costly, far less laborious in its application: it also allows the production of spirals upon surfaces, cones and curved forms.

The same apparatus is employed for cutting metal screws with a slide-rest having three slides, the lowest across the bearers, the middle parallel with them, and the top slide again across. For spirals and ornamental twists in wood and ivory the usual form of ornamental slide-rest is used. For these reasons, therefore, the apparatus is very generally adopted in foot-lathes by the professional mechanician and by the amateur; and to the latter is, perhaps, the most generally useful addition that can be made to the powers of the plain lathe.

The last wheel of the train is fixed upon the end of the slide-rest screw, this being provided with a locking-nut to secure it. A radial arm is attached to the face of the lathe-head, and the first wheel is carried by a chuck on the nose of the mandrel. This chuck is also usually arranged for cutting multiplex threads.

The mechanical details comprise the chuck carrying the work and the first wheel of the train; the radial arm, with arbors for the intermediate wheels, with various blanks, nuts, and washers, to enable the wheels with either the large or small apertures to be carried by the arbors; a socket, arranged in the same manner, to carry the wheels on the screw, and a series of about fifteen change-wheels, usually of

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brass, with from fifteen to one hundred and fourty-four engine-cut teeth. The larger wheels are bored out with plain holes to fit upon the back of the chuck, to which they are fixed by a screw-ring and washer; the smaller fit only upon the arbors, and upon the socket on the end of the slide-rest screw.

The radial arm is bored out with a hole rather larger than the back of the chuck; and around this hole, on the under surface, it has a projecting ring, which fits within a circular recess sunk in the face of the lathe-head. The arm moves partially around the mandrel as a centre, and is fixed to the lathe-head by a screw-bolt passing through a circular mortise.

The arbors for the intermediate wheels can be placed at any required distance from the mandrel, and are carried on the front side of the radial arm in a long rectangular mortise, in which they are fixed by screw-caps behind. With respect to the arbors, their shafts revolve with the wheels, fitting the holes in the smaller and carrying the larger by blanks or central filling-pieces, by which means any single wheel may be employed or any pair of wheels can be placed together on the same arbor, with either the larger or the smaller of the two next the face of the radial arm.

The socket, by means of a similar arrangement, carries a wheel, with either a large or small central hole, upon the slide-rest screw. The cylindrical portion is received within a circular recess countersunk in the end of the slide-rest, around the extremity of the screw. This portion of the socket is hollowed, and accurately fits the plain extremity of the screw, upon which it is retained by a transverse pin passing through them both. The retaining pin is slightly tapered, and in length does not exceed the internal diameter of the socket, not to impede the revolution of the latter within the circular recess. A vertical hole bored through the slide-rest gives access to the conical pin, which is driven out by a small round punch when

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it is desired to separate the socket from the screw. The wheels are carried by the socket, instead of directly upon the end of the screw, which in the latter case would have to project, in order that the removal of the socket may leave the end of the slide-rest free of any such projection—frequently very necessary in turning, other than screw-cutting, to enable the end of the slide-rest to be approached close up to the work.

The mandrel carrying the work and the slide-rest screw traversing the tool revolve at relative speeds, governed by the diameter or number of teeth and the arrangement of the wheels connecting them, the rate or pitch of the resulting screw upon the work being either a copy or a multiple of the slide-rest or guide-screw, according to the wheels employed. The simplest connection would be by two wheels, one upon the mandrel and one upon the screw. When these two wheels are equal in the number of their teeth the mandrel and the screw revolve turn for turn, and the screw produced is an exact copy as to coarseness of the screw of the slide-rest, which in the slide-rest for ornamental turning is ten threads to the inch.

The supposed two wheels, however, are not used alone in practice, for in all probability they would not place the slide-rest at a convenient distance from the work; and they turn in opposite directions. The wheel on the mandrel necessarily turns with the work towards the tool—that on the screw, therefore, turns in the opposite direction. If, as is usual, the slide-rest screw has a right-handed thread, the tool travels from left to right, cutting a left-handed thread—that is, sloping the reverse way to that of the slide-rest and to screws in general. When three or any odd number of wheels are in gear, the first and last turn in the same direction; a third wheel, therefore, is interposed between that on the mandrel and that on the

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screw, to change the direction and produce a right-handed thread. The third wheel employed is mounted upon a separate arbor or axis. It acts simply as a carrier of motion from the one wheel to the other, and in no way interferes with the results arising from their relative proportions.

A considerable variety of threads, both of whole and fractional values, may be obtained from a moderate number of change-

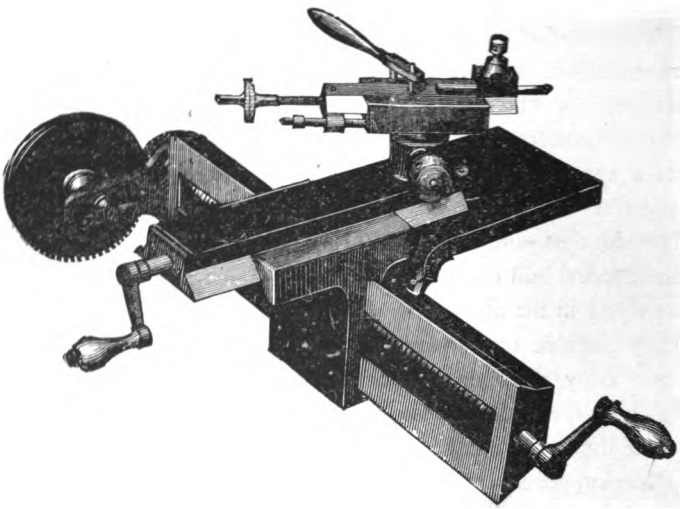

Fig. 30. "COMBINATION" REST IN PERSPECTIVE.

wheels, more especially if a fair proportion of them be multiples of six and eight.

The "Combination Slide-rest," illustrated by the two accompanying figures, is an embodiment of both band and toothed-wheel gearing applied to actuate the slide and screw. Fig. 30 is a perspective view of the complete slide-rest, and Fig. 31 shows an end view of the tool fixed on the lathe-bed. The main-slide is made in various lengths, from fifteen to forty-eight inches, the price being from £15 15s. to £30—change-

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wheels, hardwood pulley, studs, spanners, &c., all included. It will be noticed that the slide is worked by a band from the mandrel pulley, which drives the hardwood pulley fixed to a toothed-wheel, and this wheel drives another fixed on the slide-screw. Various pitches are obtained by varying the sizes of the wheels, and the pulley-wheel revolves on a stud that moves in a slot to accommodate the size of the change-wheels in use.

The maker of the "Combination" rest, Mr. Hines, says :— This most complete and useful tool is unquestionably the slide

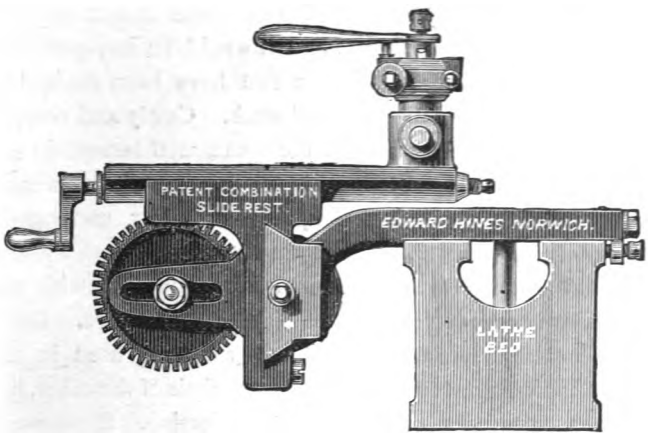

Fig. 31. End View of "Combination Rest.

rest of the future, combining the principles of the most improved screw-cutting lathes with the adaptability of the ordinary slide-rest. It is sufficiently powerful for any description of metal work usually done on the foot-lathe. It may be employed for self-acting sliding work, or turning cylindrical objects in an automatic manner, for cutting screws of the finest pitch, or those ordinarily required in mechanical work. When fitted with the various revolving cutters it is adapted for making twisted or helical work—known as Elizabethan—or any description of ornamental spiral turning.

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CHAPTER VII.

CHUCKS.

CHUCKS are appliances which are screwed on to the nose of a lathe, and used to cause the work to revolve. There are very many varieties, and it would be impossible to enumerate the various appliances that have been devised to act as chucks in executing unusual work. Costly and complicated chucks, that are used by the ornamental turner, do not come within the scope of this handbook. Plain chucks may be divided into two classes, having an easily understood characteristic. Those which are used to support work without any auxiliary aid, and those used in conjunction with the back-centre, cone-plate, or some similar contrivance. Occasionally chucks belonging to either group are used in the method indicated as forming the characteristic of the other, but this circumstance scarcely affects the distinction. Short work, held by the edges, by cement or by clamp-screws, is usually mounted on chucks belonging to the first group. Long work—that is, work which has a length greatly in excess of its diameter—is mounted on chucks of the second group.

The face-plate chuck is the most useful for mounting all work which is capable of being fixed by one surface, whether that surface is sufficiently flat for the purpose, or whether the work be levelled by packing. Face-plate chucks are usually discs of cast-iron, as large as the lathe will swing. Castings are sold by many founders with a boss ready to be screwed to fit the mandrel-nose. The face has then to be turned true and

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flat; some face-plates have numerous bolt-holes drilled through them; others have radial slots, to allow bolts to pass for clamping work to the plate. Clamps and dogs are used with face-plates to fix the work. The accompanying illustration, Fig. 32, shows a gripping dog for use on a face-plate; it is made by Mr. Hines, in sets of three or four, the price being 10*s.* 6*d.* and 14*s.* respectively. These dogs are fixed on the face-plate by the vertical bolt; the horizontal clamp screw is then used to grip the edge of the work. By attaching these dogs to a face-chuck, it is almost equal in holding power to a four-jaw chuck. Another form of dog, made by Mr. Hines, is shown at Fig. 33. This dog is used to clamp the work against the surface of the plate. The main bolt fastens the dog, and the head of the small set-screw rests on the face-plate. The right-hand end of the dog clamps the work, the grip being tightened by means of the large nut. These dogs are provided with three sets of bolts and nuts, two, three, and four inches long respectively, to accommodate various thicknesses of work. Sets comprise three or four dogs, each provided with bolts, &c.; they cost 5*s.* each. Work mounted on the face-plate must be fixed securely, and for large objects a stop is important to take the strain of the cut in turning. When the work is much eccentric, so that the weight is out of balance, a counterpoise should always be provided, so as to check the vibration that would otherwise occur when the work was revolved rapidly.

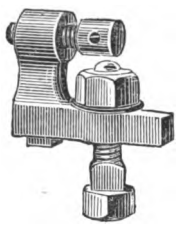

Fig. 32. GRIP DOG FOR FACE-PLATE.

Fig. 33. ADJUSTABLE DOG FOR FACE-PLATE.

The four-jawed chuck illustrated by Fig. 34, borrowed from "Lathe-work," is the most efficient and useful chuck for all

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kinds of work within the range of its action, and that can be clamped by the edge. The four jaws, or dogs, are moved independently by means of the screws. One of these screws is shown in elevation, with the chuck broken away to show how the screw is fitted in its bearings. These chucks should always be made the full diameter that the lathe will carry. The lower right-hand part shows the construction of the back,

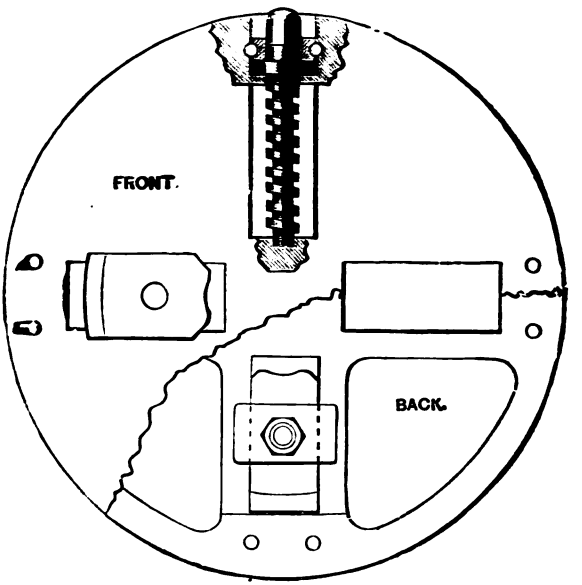

Fig. 34. FOUR-JAW CHUCK.

which has projecting fillets around the edge and along the sides of the slots in which the jaws slide. The face of the chuck is quite flat, and the thickness of the metal may be about one quarter of an inch; the fillets projecting about three quarters. Where the screws pass through the rim, there is a slight extra projection in the form of a boss. The jaws, or dogs, are usually forged in iron, and after being fashioned

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to shape are case-hardened. The hole shown in the left-hand jaw is tapped to take a bolt, for the purpose of attaching anything in the form of an auxiliary jaw, should it be required.

An elevation of a four-jawed chuck, manufactured by the Britannia Company, is shown at Fig. 35. This chuck has square holes in it to take such dogs as have been illustrated by Figs. 32 and 33. The sliding-dogs are shown with three steps, so that they will grasp work of various diameters. This illustration may serve to elucidate the construction of the previously described chuck.

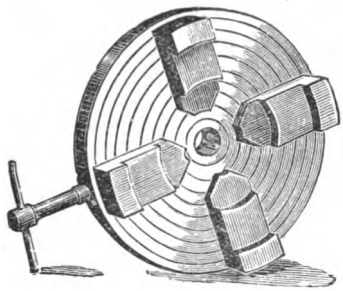

Fig. 35. ELEVATION OF FOUR-JAW CHUCK.

The point-chuck, illustrated by Fig. 36, borrowed from "Lathe-work," is the most useful chuck for metal turning. The practice of mounting work for turning between centres is of universal application. Extreme facility and great effectiveness combine to make chucking between centres the most general method of proceeding, and when possible it is adopted. Work that has been properly centred may be taken off the lathe and re-mounted at any subsequent time, with the

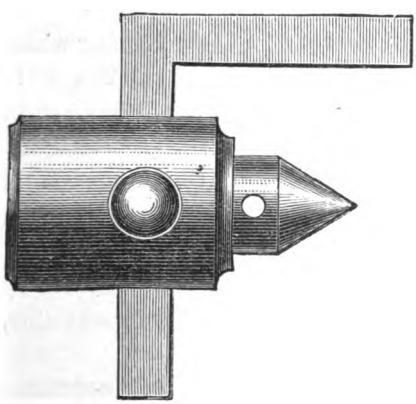

Fig. 36. POINT CHUCK.

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certainty of its running perfectly true. Other methods of chucking do not allow of this being done without considerable trouble; and for these reasons all work should, if possible, be chucked between centres. Every metal turner's lathe is provided with a point-chuck, and the construction of the appliance is too well known to need much description. The point should be made of steel, and left soft, so that it can be turned true at any time that such an operation is necessary. Cone centres should be turned to an angle of sixty degrees; a handy gauge for the purpose of verifying the accuracy of this angle is made by filing a notch, in a piece of sheet metal, with a triangular file. Large lathes usually have the cone centres fitted into the mandrel itself, a hole being drilled up it for that

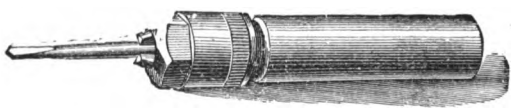

Fig. 37. "ESSEX" SELF-CENTRING CHUCK.

purpose. The centre is thus kept near to the bearing, which conduces to steadiness in turning. A disc of cast-iron is, in these cases, screwed on to the mandrel-nose; it has a short straight pin screwed into it to catch the tail of the carrier. This chuck is called a catch-plate. Usually two or more holes are drilled at different radial distances, so that the pin may be shifted to suit various sizes of work. A modification of this form is sometimes used instead of the chuck illustrated by Fig. 36; and though not generally employed on foot-lathes, yet it is really a stronger chuck and easier to make.

The "Essex" chuck, shown at Fig. 37, is a useful appliance for gripping small wire. It is made by the Britannia Company; the price with two jaws, to hold any size from one-quarter inch downwards, is 10*s*. This chuck is very simple in construction, as may be inferred from the illustration. It con-

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sists of the shank, which is left soft so that it may be fitted into any suitable chuck. This shank is about two-and-a-half inches long, and five-eighths in diameter. On the outer end a fine thread is cut, and the centre is bored out about five-sixteenths. A cap is fitted on the screwed part, and it has the end shaped, as shown, to fit a spanner. The jaws of the chuck are made of steel, hardened and tempered; one is illustrated by Fig. 38. There are two jaws supplied with the chuck—one for small and the other for large sizes. As may be seen by Fig. 38, the jaws are split into three, and the chuck is self-centring. The jaw is put in the shank; when the cap is screwed on the three parts come together, and grip any object that may be between them. This chuck is very useful for holding drills and any round wire within its capacity. A larger size, taking from half-inch diameter, is also made. It has four jaws to grip any size from half-inch to the smallest; the price is £1 5*s*. These chucks are easily fitted to any lathe.

Fig. 38. JAW OF "ESSEX" CHUCK.

Drill-chucks of the best form are shown by Figs. 39 and 40. The two chucks are very similar in construction; they are easy to make, and both are thoroughly good. The illustrations are borrowed from "Lathe-work." The drawings are made from chucks which I have had in use for years, and it will only be necessary to enlarge them proportionately to make working drawings. It is best, and really cheapest, to have several chucks for different sizes of drills, as these should be made from steel of a size approaching that of the finished drill. If the drills vary from one-eighth to five-eighths of an inch in diameter, they should be made of three or four sizes of steel, and each size requires its special chuck. Drills to bore five-eighth holes should be made from steel at least half-inch in

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diameter, and drills one-eighth will be very troublesome to make from steel much larger than one-eighth diameter. I use chucks bored to one-eighth, one-quarter, three-eighths, and half-inch, and these take all the drills of any size up to five-eighths. Those smaller than one-eighth I fit into brass sockets which have been previously fitted to the chuck. Fig. 39 shows a section of a chuck for one size only. This is made of iron, fitted to the mandrel-nose and bored out, slightly tapering to receive the steel nozzle, which is turned to fit, and driven into the iron very tight against the shoulder shown. The nozzle is bored out with a tapering half-round bit, as shown by the shaded hollow channel, and a mortise hole is cut diametrically across the nozzle at the end of this tapering hole.

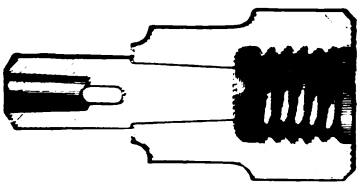

Fig. 39. DRILL CHUCK WITH TAPER HOLE.

For convenience in handling, all the corners are rounded off, and the outside of the entire chuck turned up true. The drills to fit this chuck are made with a tapering shank, the extreme end of which has two flats filed on diametrically opposite sides, which enable it to pass into the mortise hole, and by this means the drill is prevented from turning round in the chuck. This is an excellent method, but having to fit the drill-shanks tapering is rather troublesome when an odd one has to be fitted. Fig. 40 shows a chuck with a nozzle which may be

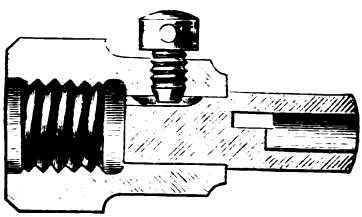

Fig. 40. DRILL CHUCK WITH PARALLEL HOLE.

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taken out and changed for another of different bore. The body is the same as in the previous figure, but it has a capstan-headed screw tapped through. This is sufficiently long for the point to project slightly through the centre-hole when the screw is screwed home. This centre hole is bored out quite parallel, and into it are fitted the shanks of drills in the same way as is shown with the nozzle in the figure. Pieces fitted in have a facet filed on them with a half-round file, to allow the point of the screw to take firm grip. The nozzle-piece is fitted tightly, but so that it can be drawn out with the fingers. It is secured by the clamp-screw The end of the nozzle is bored up parallel with a half-round bit, and the mortise-hole is cut through it on one side of the diametrical line. Many people, instead of taking the trouble to cut a mortise-hole, simply file a slot from the side to the diameter line, and produce the same effect. This is, however, a bad plan, as the solid metal, shown above the rectangular mortise in the figure, affords considerable support to the nozzle, which, if cut half off, as by the other plan, is very apt to bend or break. The drills are fitted to this nozzle parallel, and have half the diameter filed off at the end to form a piece to project into the mortise, just like the drills are fitted in ordinary drill-stocks. Several nozzles with different sized bores can be fitted to and used with the same main-chuck. To get the drills out of sockets made like either of the above a lever is used, inserting it in the mortise behind the tail end of the drill.

Fig. 41 shows an exceedingly good chuck for gripping rod-metal of any diameter within its capacity. The original chuck, from which Fig. 41 results, was made by an engineer of high attainments, though an amateur, in whose workshop I saw it some fifteen years ago. Since then I have used a similar chuck almost constantly, and unhesitatingly give it first place amongst chucks for similar purposes. Some drawings are shown

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in "Lathe-work." The chuck shown at Fig. 41 is made by the Britannia Co.; it is three and five-eighths inches in

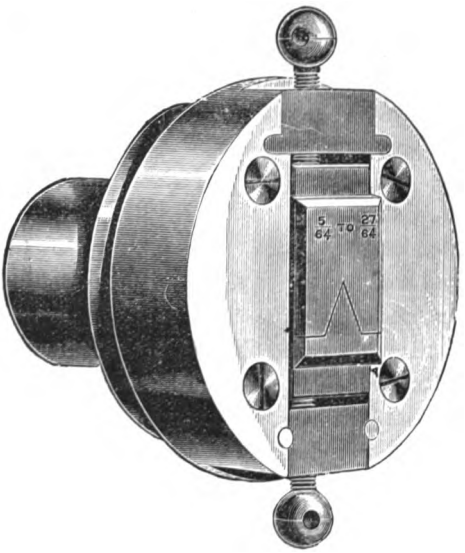

Fig. 41. UNIVERSAL CHUCK.

diameter without the screws. The dies slide in grooves cut in the solid, and are made to bite by means of the round

Fig. 42. DIES FOR UNIVERSAL CHUCK.

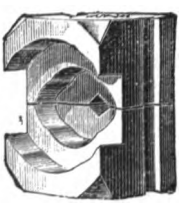

Fig. 43. DIES FOR HOLDING SMALL DISCS.

[redacted] screws shown at top and bottom of the illustration. [redacted] through which the screw passes is fixed in the lower

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side by two pins shown. The upper screw and its nest slide out easily, so that the dies may be readily changed. The dies used consist of four pairs; three like those shown at Fig. 42, and one pair like those shown in the chuck Fig. 41. These latter take all sizes under twenty-seven sixty-fourths. As a rule wire under one-sixteenth diameter is not used on a five-inch lathe, and the dies are much improved by removing the sharp edg of the lower die. The other three pairs take respectively from quarter to half inch; half to three quarters, and three quarters to one inch.

Dies for holding discs such as washers are made of the form shown in Figs. 42, 43. These take from eleven sixteenth inch to one and eleven sixteenth inch, and a careful inspection of the illustration will show the circular gripping part to be made in a series of circles—usually three representing the largest, the smallest, and the midway diameters—so as to distribute the grips around the object. Made in this manner the dies grip at four points work of any diameter.

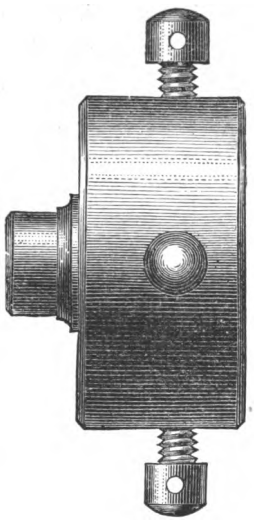

Fig. 44. CUP CHUCK.

It should be noted that this chuck, though not self-centring, is manipulated so quickly and easily that work may be set true in a few seconds. The screws are sufficiently slack to be turned with the fingers, and only the final punch is made with a tommy. The face-part of the chuck is intended to be fitted to a base, specially screwed to the lathe nose; the four screws show the means of attachment.

A cup-chuck is illustrated by Fig. 44, the engraving being borrowed from "Lathe-work." Four screws are put radially

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into the rim of the chuck at equidistant places. Cup-chucks, as illustrated, are employed principally to hold short objects, such as nuts or short rods; these may be turned unsupported at their outer end. The object to be held in the chuck is gripped by the points of the screws, and these are each screwed in as required to centre the work. The projecting screw-heads are often in the way, and apt to cause damage. The points also badly mark the work they grip, and these circumstances are somewhat of a drawback to the use of screw cup-chucks.

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CHAPTER VIII.

HORIZONTAL AND VERTICAL CUTTER-SPINDLES.

CUTTER-SPINDLES are such useful adjuncts to the ordinary foot-lathe that when once they have been used few care to work without them. A plain drilling-spindle is shown at Fig. 45, which is borrowed from "Lathe-work," in which treatise the construction is fully explained. The shank is made of square iron, the finished size of which is double the difference between the height of the lathe-centres and the height of the top of the slide-rest. The shank is bored through to take the spindle. This spindle may be any size, from three-eighths to one inch in diameter for a five-inch lathe, according to the work to which it is to be applied. A nose like that of the lathe-mandrel is shown in Fig. 45, but an internal thread, as shown in Fig. 49, is frequently preferable, and for small drilling-spindles a plain hole, like that shown in the drill-chuck, Fig. 40, is frequently used.

The sectional drawing, Fig. 45, shows the spindle fitted in steel collars. The end motion is confined by an abrupt cone at the nose-end, and the pulley bearing against the face of the back-collar. The collars are made to abut on shoulders in the shank, so that they cannot be forced inwards by the lateral pressure on the spindle. The collars are coned, tapering about half a degree, to fit the bearings of the spindle. The pulley should be as large as the slide-rest will allow, and a V shaped groove will be more serviceable than the half-round one illustrated in Fig. 45.

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Overhead gear and dividing apparatus are required when using a drilling-spindle; it will be found useful for many purposes. Apart from drilling simple holes, it may be used for grooving taps, making drifts or punches for triangular, square, hexagonal, octagonal, and other shaped holes; also for squaring up the flats of bolt-heads, and shaping up prismatic pieces in wood or metal. It may be used on surfaces for cutting slots and grooves of all shapes; in short, the drilling-spindle may be applied to so many purposes that it is scarcely possible to enumerate them all.

The drilling-spindle illustrated has the shank made of a square

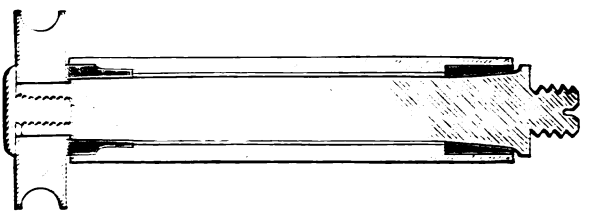

Fig. 45. PLAIN DRILLING-SPINDLE.

bar of iron. This may be held in position on the slide-rest by means of the tool-holder, if a suitable one. Some tool-holders will not allow such a large piece of metal beneath them; and for use with them another form of drilling-spindle must be chosen. The slide-rests that have been illustrated show various forms of tool-holders. The one which I consider excellent is that shown on the Metal Turner's Slide-rest, Fig. 29. Another form of tool-holder, invented by Professor Willis, has found favour, and is a very efficient contrivance. The drilling-spindles used on ornamental turning-lathes are made like that shown by Fig. 45, but they are much lighter.

The subsequent illustrations show a drilling-spindle somewhat more elaborate in construction. It is applicable to a

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more extended range of work, including wheel-cutting, when used in conjunction with the apparatus described in Chapter IX. The entire apparatus, from which the drawings for the illustration were made, is fitted to a five-and-a-half inch centre lathe. Some of the figures are full size, some half size; when dimensions are given they refer to the instrument above named. With the casting, which carries the bearings of the spindle fixed on the top of the slide-rest, all the requirements of a driller are attained. In this position the universal cutter-frame forms a very serviceable tool. With a suitable cutter it will face up the flats of nuts and bolt-heads in a style and at a speed that will consign the file to oblivion for such purposes. The spindle is fitted so that it is precisely on the line of centres, and thus it forms a miniature lathe with which the ordinary back-centre may be used. On this it is comparatively easy to turn delicate work, that could not be mounted on the mandrel direct. Figs. 46 and 47 are specially intended to illustrate this part of the apparatus. So far as drilling, fluting with a drill, and a small lathe are concerned, all those parts of the appliance appertaining to these are found here, and the part shown at Figs. 46 and 47 will be a very useful tool in itself.

The frame is of cast-iron, a flat fiddle-shaped piece, five-and-a-half inches long, with a groove along the centre, and two lugs or ears cast on it, which take the collars of the bearings. When making the instrument the bottom of the casting is first made flat. A file may be used to effect this purpose; but a far better plan is to turn it on the lathe. The casting may be easily bolted on to the surface-plate by means of a couple of clips, the casting being supported by parallel strips of packing under the flat part, and keeping the lugs from contact with the surface-plate. Thus chucked, the whole of the bottom, excepting where the clips bite, may be turned true with the slide-rest, and it will then be perfectly flat. A few

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strokes of a file will suffice to remove the slight excrescences above mentioned.

Laying the casting with its flat side downwards, the position

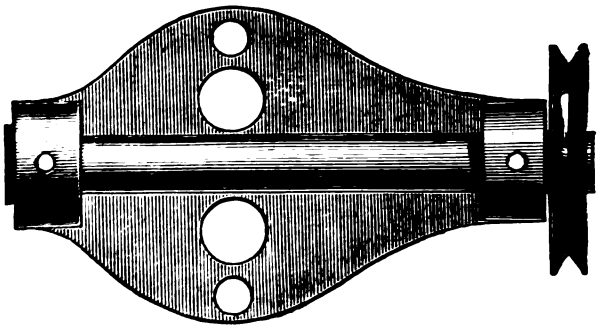

Fig. 46. PLAN OF DRILLING-SPINDLE.

of the bolt-holes shown may be determined. First, a central hole, which is not shown, owing to the superposition of the spindle, about three-eighths inch in diameter, is carefully bored. This hole must be very accurately centred, or the

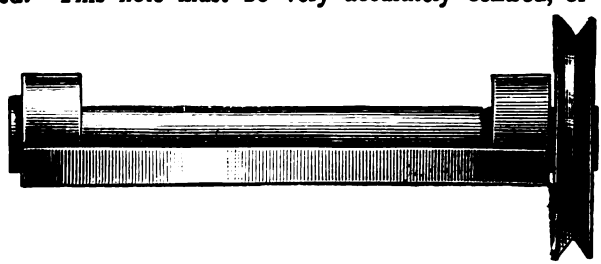

Fig. 47. ELEVATION OF DRILLING-SPINDLE.

whole frame will be one-sided. Level with the centre of this hole mark a line at right angles to the position of the spindle. On this line mark the four holes seen in Fig. 46. The small ones are one-and-five-sixteenths of an inch from the centre, and three-eighths of an inch diameter. They are to take the bolts which allow of angular adjustment to the spindle. The larger

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holes are on the same line. Their diameter is five-eighth inch, and they are bored in such a position that they are midway between the inner edge of the small holes and the spindle. These holes are to allow the top-bolt of the slide-rest to pass through, and by this means the frame is held on to the top of the slide-rest. A special form of "washer" is usually necessary, so as to distribute the pressure of the nut on the bolt as far as possible over the frame.

The correct height at each end, one of which is shown at Fig. 48, for the holes to take the collars, can now be easily marked by laying the frame on the top of the slide-rest, and scratching the lugs with the back centre-point. With this mark as a guide, centre the lugs as truly as possible with a centre-punch, and bore them through. Sometimes it is more convenient to use the scribing-block for marking the height of centres; or even the dividers are sometimes more handy to use with one leg against the lower finished surface. When the collar-holes have been drilled through, it is advisable to mount the frame by these holes between centres, and true up the ends flat. This precaution will give a better entry for the drills with which the collar-holes are subsequently enlarged. The ultimate finished size will be nearly three-quarters of an inch, but it must be bored by means of a boring-bar between centres, to ensure correctness in height.

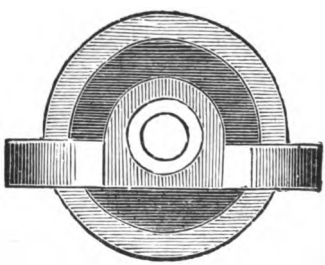

Fig. 48. END OF DRILLING-SPINDLE.

When the holes have been drilled to about five-eighths of an inch, or even larger, if they are very nearly true to height, fix the frame carefully on the top of the slide-rest. Mount a boring-bar of suitable size between the centres, and take a cut

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through the holes. The position of the holes may be adjusted slightly during this operation, if they have become somewhat eccentric during the previous drilling. The front-hole is to be bored out three-quarters of an inch, the back one eleven-sixteenths of an inch, with a short recess three-quarters of an inch in diameter. The collars shown in section, full size, at Figs. 49 and 50 will show the size of the holes. When the holes are finished, it will be well to put the frame between centres again and true up the ends, if they are not quite square and flat. The inner sides of the lugs and also the top of the fiddle can be smoothed with a file, and the entire casting made fairly smooth and square on the edges. Two small holes for oil must be drilled in the middle of the top of the lugs, as shown in Fig. 46.

The spindle, or mandrel, will next claim attention. This is made of a piece of good cast-steel, three-quarters of an inch diameter, and six inches in total length when finished. Good steel must be selected; and as the collars are made of the same material, it will be advisable to cut off a piece one-and-a-half inch long with which to make them, and anneal it. Centre the steel for the spindle, mount it on the lathe, and turn the ends true. It will next have to be bored through the entire length. A hole three-sixteenths of an inch in diameter must be made first; this work is most conveniently done with the aid of a boring-collar. A half-round bit will bore true and parallel. Enter the bit true, lubricate it well with soapy water, and bore through. This done, countersink the ends well. With a tool in the slide-rest take a cut along the cylinder from one end to within one-quarter of an inch of the other. By this means reduce the diameter to a trifle over five-eighths of an inch, except at one end, where the full diameter is left for a length of one-quarter of an inch. This end, Fig. 49, will form the shoulder of the spindle for the chucks to screw against.

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Sectional views of the two ends of the finished spindle are shown at Figs. 49 and 50. The nose end is screwed with a $\frac{1}{16}$ inch Whitworth thread, forming a female nose. The spindle is bored with a five-sixteenths of an inch hole to within half-an-inch of the tail-end, where it is tapped with a quarter-inch thread. Fig. 50 shows this. The nose part is turned out accurately true and parallel, about three-eighths of an inch deep; this forms the fitting of the chucks. The threaded part follows, as shown. The collars, shown in section by Figs. 51 and 52, may next be prepared. Mount the piece of steel previously mentioned in a cup-chuck or die-chuck; see that it runs quite true; then bore it out to half-inch diameter. The

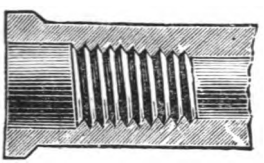

Fig. 49. NOSE END OF SPINDLE.

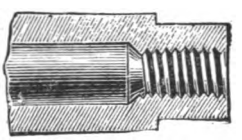

Fig. 50. TAIL END OF SPINDLE.

tube may then be cut in two. Set the slide-rest to turn conically about half-a-degree taper, and enlarge the hole in the collars till nearly to size, then carefully anneal them. Proceed to finish the front collar, Fig. 52, by turning it out to just five-eighths of an inch diameter, making the hole as smooth as possible by using a sharp tool in the slide-rest. Turn down the spindle conically to fit the collar, and then, using the mandrel as an arbor, turn the outside of the collar true to fit the hole in the casting, where it will have to be fixed. The collar will now have to be mounted in a wood chuck, so that the cone may be ground out with a lead grinder dressed with emery. By this means it will be got very smooth, and the spindle can then be further reduced in diameter till it enters the collar nearly to the shoulder. The

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back-collar, Fig. 51, is then got to size by the same processes as have been described. Each collar has a small hole drilled through it, to allow the oil used for lubricating to reach the inside. These holes must be drilled so that they will come opposite the oil-holes in the casting. The front-collar must be mouthed out as shown, to take the second cone on the mandrel. The back collar must have its back end ground quite flat to form the end bearing. Small channels should be filed inside each cone leading from the oil-holes towards the ends, to allow the oil to distribute itself along the bearings. These channels must be filed with a round file. If cut in at a sharp angle the collars will probably split when hardening.

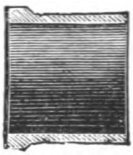

Fig. 51. SECTION OF BACK-COLLAR.

Fig. 52. SECTION OF FRONT COLLAR.

Hardening the collars will be the next process. Every care must be exercised to ensure equal heating all over. This is rather difficult. It often happens that an inexperienced manipulator will allow one part to be burnt before another part is hot enough to harden. A kind of muffle is useful to regulate the heating process. Clean cold water is as good as anything to harden in. The collars need not be tempered at all. They are forced into the holes in the casting by the aid of a bolt put through the collars, which are drawn together by screwing up the nut on the bolt. When they are adjusted to position the spindle may be finally fitted. This is done by reducing it gradually till it very nearly reaches home. The bearings are then ground to fit with oilstone dust. Grinders, made of brass or gun-metal turned to the precise shape of the mandrel cones,

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may be used for grinding out the collars when these are in position, if requisite.

The spindle up to now has been considered as soft, and so it may be left. The soft steel will run for a long time in the hard collars. To harden a spindle is a difficult job, and one that need not be undertaken. When the spindle has been fitted to its bearings, the neck, shown on the right in Fig. 50, must be turned down to receive the pulley. This pulley has been shown in Figs. 46 and 47. It may be made of cast-iron or other metal. An angular groove affords the best grip for a band. The pulley is fitted on to the neck of the spindle, and is there held by the screw which fits in the thread shown in the section, Fig. 50. A small pin in the spindle, with a piece projecting to catch in a notch cut in the pulley, will prevent the latter turning without the spindle. A very thin steel washer resting against the shoulder of the neck will be necessary to bear against the back end of the collar, and prevent endshake in the bearings. A steel washer is

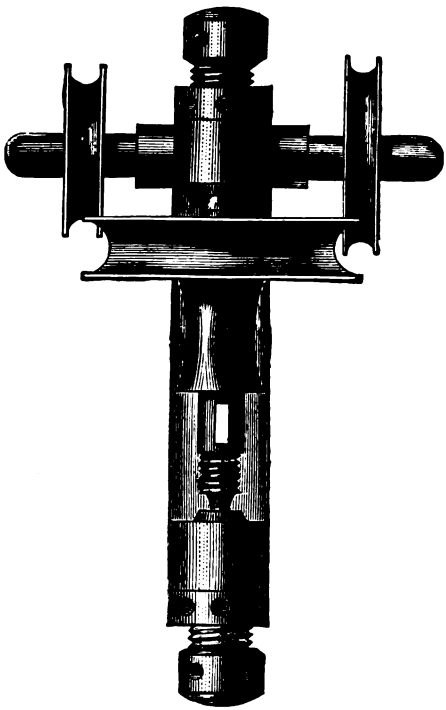

Fig. 53. VERTICAL CUTTER-FRAME.

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preferable to allowing the pulley itself to form the bearing. The drilling-spindle is now completed. Apart from the remainder of the apparatus described in Chapter IX., it forms a most useful appliance. When such a contrivance has once been established in connection with a lathe, it will be constantly brought into requisition.

A spindle revolving vertically is useful for many purposes, for which a horizontal spindle, such as last described, cannot be employed. The accompanying illustration, Fig. 53, borrowed from "Lathe-work," shows a vertical cutter-frame adapted for wheel cutting, and similar purposes. The spindle is steel, and has a large sized pulley fitted to it, to be driven from the overhead gear. The two guide pulleys, or runners, are of different sizes, so that the driving-band is led on and taken off at different heights. The spindle has pointed ends running in countersunk set screws. By means of these, the height of the cutter may be adjusted to a nicety. The cross mortise hole is useful principally for single-tooth fly-cutters; circular cutters, such as are described in a subsequent chapter, are held on the spindle by a nut, the screwed part for which is shown. Full particulars of the construction of this cutter-frame are contained in the treatise above named, from which the illustration is borrowed.

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CHAPTER IX.

UNIVERSAL CUTTER-FRAME.

THE cutter-frame which is illustrated in this chapter combines in a small and compact form the essentials of what often form several distinct machines. As described in the last chapter it will serve as a plain horizontal driller useful for drilling holes in a division plate, or for fluting, and also serves the purpose of a small lathe, which is often very handy for light work. Placed vertically it will cut teeth in wheels of any size within the compass of the lathe to which it is attached; or, with a suitable cutter, taps may be grooved by it. When inclined slightly from the vertical it will cut wheels with angular teeth, and is exceedingly handy for cutting the spaces in worm wheels. The vertical motion allows the height of the cutter to be adjusted to the greatest nicety. With the spindle placed horizontally, grooves are easily cut across the face of a chuck or any object fixed to it. By this means the base-plate of an oval or eccentric chuck may be readily grooved along the edges, with the absolute certainty that the grooves so made will be true in every way. The grooves of a die-chuck may be made in the same way, and innumerable other operations that so severely task the skill of a filer may be done quicker and better by the aid of this apparatus.

The vertical position of the spindle is necessary for wheel-cutting, and also for grooving when circular cutters are used, this being the most economical way of doing such work. The angular adjustment is also very handy for many purposes. A

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vertical motion is indispensable when the height of the cutter has to be adjusted, as is the case in wheel-cutting. In some of the apparatus of this kind the sliding-piece, which carries the cutter-frame, is fitted in dovetailed grooves, and much labour is expended in fitting the saddle to these grooves. It is, however, only so much work wasted, because a plain slide, as shown, with a bolt to fix the saddle when the height has been adjusted, is even more effective, and far less trouble to make.

The illustrations are all drawn to scale, as explained in the last chapter. Fig. 54 is a side-view of the complete apparatus, showing the shape of the bracket which forms the foundation. This bracket has its lower face planed, turned, or filed up flat to fit on the top of the slide-rest. Fig. 55 is a back-view, showing the leading-screw by which the height of the cutter-frame is adjusted. Fig. 56 is a view of the front. Here the spindle, or mandrel, is shown. Fig. 57 is a view from above, and it shows the slot through which the bolt on the top of the slide-rest passes. Having indicated the general purport of each figure, I will proceed to particularise each. The drawings are made from an apparatus fitted to a five-and-a-half inch centre lathe, and the dimensions, where given, refer to that sized tool. It will be very easy to reduce or enlarge these dimensions to suit a smaller or larger lathe.

Fig. 54 shows the cast-iron bracket, the base of which is four-and-a-half inches by three-and-a-half inches, and fully half an inch thick when finished. The upright is five-and-a-half inches high, and the same width and thickness as the base. The angle is strengthened by two webs from three-eighth inch to half-inch thick, and placed very near the edges, as may be seen in Fig. 55. A strip is shown in Fig. 54, secured by three screws to the edge of the upright. Another strip precisely similar is secured in the same manner on the opposite

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side. These strips are conveniently made of bar-iron three-quarter inch wide by one-eighth inch thick and five-and-a-half inches long. They have to be filed up true and square. The edges of the upright angle-piece, of course, require to be made flat first. At the top is seen the square end of the leading-screw by which the height is adjusted. The saddle, moved

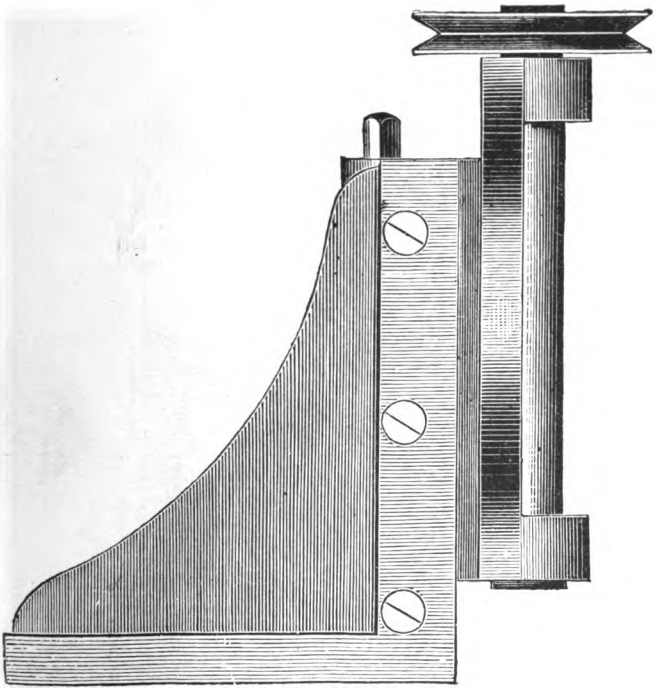

Fig. 54. UNIVERSAL CUTTER-FRAME.

by this screw, is shown projecting slightly in front of the strip. Against the saddle is the frame in which the spindle is fitted. The spindle and the pulley by which it is driven are also shown, but the illustrations given in Chapter VIII. will give the details more clearly.

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Fig. 55 is the back of the bracket, where the edges of the webs are seen. The two strips are shown edgeways, with the heads of the six screws by which they are secured showing. The leading-screw need not be a large one, three-eighths of an inch in diameter will answer. It is about five inches long. A

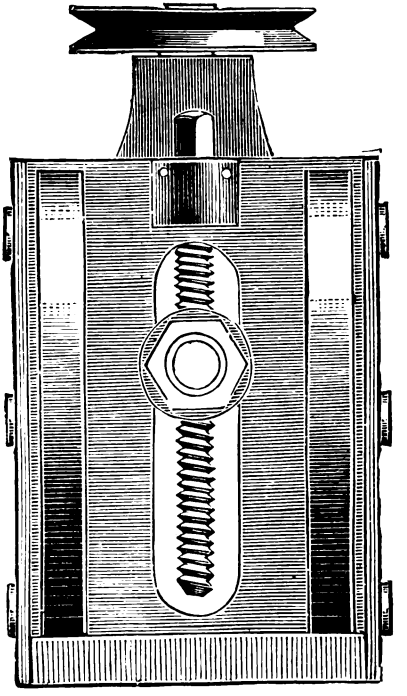

Fig. 55. Back of Universal Cutter-Frame.

small projecting piece is cast on the back of the upright to form the bearing of this screw. The screw is kept in by a collar held by the two pins shown. The slot down the centre is about seven-eighths of an inch wide; it is cast in. The length is sufficient to allow about three inches of traverse to the slide. The hexagon nut fits a bolt driven through the

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centre of the saddle-plate. It is by this that the saddle is fastened tight when the correct height has been attained. The leading-screw has its lower end perfectly free. It would be no better, but the fitting would be much more difficult, if this

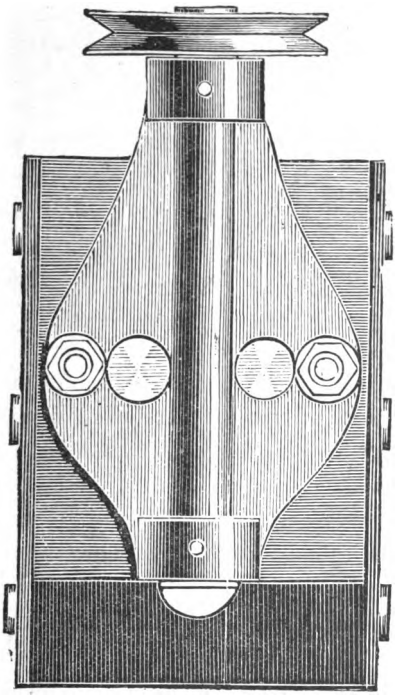

Fig. 56. FRONT OF UNIVERSAL CUTTER-FRAME.

screw were pivoted into a hole in the casting, as shown in the four-jaw chuck (Fig. 34).

Fig. 56 is the front of the apparatus. The spindle stands vertically in the centre. It is six inches long, and three-quarters of an inch in diameter at the largest part—that is, at the lower extremity where the shoulder is. The full-size drawings of the two ends of the spindle in section (Figs. 49

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and 50) show this better. Instead of having a nose as usual for the chucks to screw on, this spindle has an internal thread —that is, a female screw. Behind the first collar the mandrel is five-eighths of an inch in diameter, and parallel to the back-collar, where it is coned to fit the bearing, and then turned down to take the pulley. This is seen better in the full-size drawings above alluded to. The casting, which carries the spindle, has been described in the previous chapter. It is about seven-sixteenths of an inch thick, with a groove down the centre to allow the spindle to pass. The lugs in which the collars are fixed are semi-circular projections, five-eighths of an inch thick. Fig. 48 will show the form of these lugs as seen endways. The two hexagon nuts in Fig. 56 are to clamp the frame against the face of the saddle. The heads of the bolts fit in a circular T groove turned in the thickness of the saddle, and which enables the frame to be swung round entirely. This is much more convenient than having curvilinear slots in the top casting.* The T groove is shown in Fig. 60. The frame turns on a pivot left projecting from the end of the bolt by which the saddle is clamped to the bracket. This bolt is shown, full size, at Fig. 58. The two large holes through the top casting, in a line with the hexagon nuts, are to take the bolt of the slide-rest when the spindle-frame is fixed on it alone in a horizontal position. The semi-circular opening seen near the shoulder of the spindle is part of the slot shown in Fig. 55. The saddle is shown in the position it would usually occupy when the spindle was used vertically. A cutter screwed on a chuck, fitted in the spindle, would be somewhere near the level of the lathe-centres. The top of the saddle, which is simply a rectangular plate of cast-iron four-and-half inch by three-and-half inch, and fully half-inch thick, is shown with its top edge level with the top of the bracket. The lower edge is about an inch from the base. The two sides fit tightly between the strips of

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iron secured to the sides of the bracket. These confine the side-shake of the saddle.

Fig. 57 shows the top of the complete apparatus. Here the open slot is to allow the main bolt of the slide-rest to pass. A thick washer, or, more properly speaking, a sleeve, is put on the bolt to take the pressure of the nut. The length of the slot allows considerable space for adjustment as to position on the top of the slide-rest. In this illustration the top of the leading-screw is shown, but properly it should be nearer the face of the bracket, so as to clear the nut on the tightening-up bolt (Fig. 58). The diameter of the pulley is here shown; it is two-and-half inch. This is a convenient size, though for some work a larger one is wanted. It is easy to make one of hard wood for such occasional work. The screw holding the pulley on the spindle is shown, also the edge-views of the various slides, by which their thickness may be gauged. By comparison with the three illustrations previously described, it will be easy to trace all the other parts of Fig. 57.

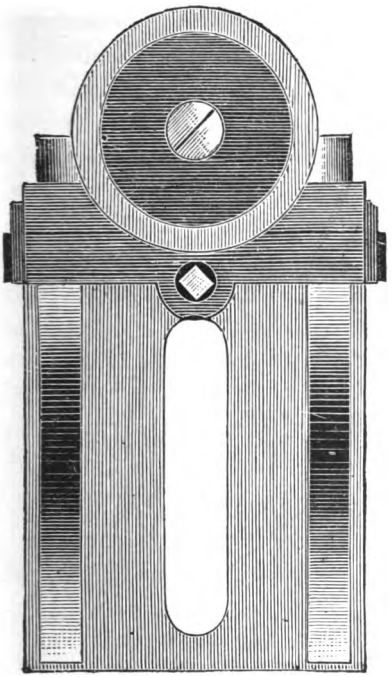

Fig. 57. TOP OF UNIVERSAL CUTTER-FRAME.

The bolt by which the cutter-frame is held firmly against the

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bracket is shown at Fig. 58. It is made from a piece of round iron one-inch in diameter and one-and-seven-eighths inch long; this is centred, and turned to the shape shown by the illustration. The projecting piece at the right-hand end is the pin on which the cutter-frame swivels angularly. Immediately behind it is the collar, one inch in diameter and one eighth inch thick. A conical part follows; this is fitted into the sliding plate, which is attached to the face of the bracket. The bolt is thus driven tight into the plate. A pin is necessary to prevent the bolt turning under the influence of screwing up the large nut at the back. The plain cylindrical part which follows is that which slides in the groove of the brackets. The hole through it shows the place for the leading-screw which actuates the slide. The left-hand end of the bolt has a five-eighth of an inch thread cut on it to take the nut by which the sliding-plate is secured to the bracket. The face of the slide is recessed out to take the collar previously mentioned, so that the bolt is wholly below the surface, except, of course, the projecting pin on which the cutter-frame turns. A large washer is required between the back surface of the bracket and the face of the large nut.

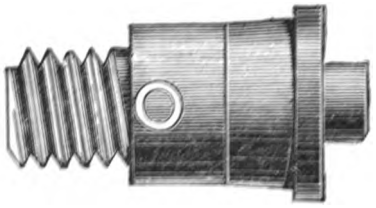

Fig. 58. MAIN-BOLT.

Fig. 59. LEADING-SCREW.

The leading-screw to actuate the slide is shown at Fig. 59—the upper end only is illustrated, to economise space. The thread is a quarter-of-an-inch diameter and four inches long from the lower side of the collar, the total length being five inches. Some particulars of this screw have already been

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given. The end is squared as large as possible to receive a handle when the height of the slide has to be altered. An ordinary Whitworth thread is as good as any for this screw. The hole in the main-bolt, Fig. 58, through which it passes, must be drilled and tapped when the slide is fixed against the bracket, so as to ensure the tapped hole being precisely opposite to the one which forms the bearing of the screw collar in the bracket.

The sliding-plate is shown half-size by Fig. 60, which is a sectional view taken through the middle. In the centre the hole for the main-bolt, Fig. 58, is seen. It is shown recessed out to take the collar of the bolt. Concentric with that hole a groove is turned in the substance of the plate. This groove is

Fig. 60. SECTION OF SLIDING PLATE.

shaped like an inverted ⊥, as shown in Fig. 60. The extreme depth is about three-eighths of an inch, and the widest part of the T is about half an inch, the narrow groove being three-eighths of an inch wide. The diameter of the circular groove is two and five-eighths of an inch, so as to bring it just under the holes shown in the cutter-frame.

To make this T groove properly, special care is necessary to ensure both undercut sides being alike. The method of procedure is this: First chuck the plate securely on a face-plate or other convenient chuck. Then turn a recess three-eighths of an inch wide and nearly the same depth, leaving two-and-a-quarter inch of metal inside. This may be done with a thin flat-nosed slide-rest tool. To undercut the T, a pair of L-shaped tools will be wanted. The cutting edge of the L must project at least one-eighth of an inch, and the total width of shank and cutting-lip must not exceed three-eighths of an inch,

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otherwise it will be impossible to get the tool into the groove. By means of the right and left L tools the groove is undercut on both sides as nearly as possible square. The upper surfaces of the undercut portions form the bearings of the clamping-bolts, and it is, therefore, necessary that they should be level. To ensure this, it is best to finally finish them with one tool.

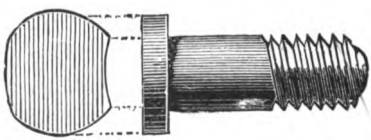

Fig. 61. CLAMPING-BOLT.

This is first used in the ordinary way, to finally smooth one of the undercuts. Its depth is carefully noted by the position of the slide-rest screw. The tool is then withdrawn, and wound over to the further side of the groove, where it is again introduced to precisely the same depth. The lathe is set in motion in the contrary direction, and the other undercut is finished in that manner. Thus absolute coincidence in depth is ensured.

This circular groove allows the cutter-frame to be swivelled round entirely. With curved slots, as usually seen, the angular adjustment would not be sufficient, as it is necessary to move the frame through an angle of 90 degrees to adjust it from a vertical to a horizontal position.

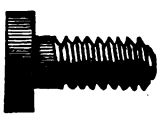

Fig. 62. SCREW.

In order to introduce the two bolts, one of which is shown at Fig. 61, into the T groove, a hole is necessary at the back. A section of this hole is seen in Fig. 60, at the left-hand part of the groove. It must be five-eighths of an inch in diameter, and may be at any part of the circle. In drilling it, a flat-ended rose-bit should be used.

The two clamping-bolts for the angular motion are precisely alike. One is shown in Fig. 61. The bolt is three-eighths of an inch in diameter, and one-and-a-quarter inch long over all. The head is five-eighths of an inch in diameter, with circular

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portions filed off on two opposite sides, so as to reduce the width of the head to half-an-inch, and allow it to go into the T groove. The portions filed off leave faces by which the head of the bolt is held in the groove, so that it cannot turn round when the nuts are being moved. The plan view of the head, shown to the left of Fig. 61, shows the form it should have. The head is just under one-eighth of an inch thick. Fig. 62 shows one of the six screws by which the strips are secured to the upright sides of the bracket. It has a quarter of an inch thread, and is three-quarters of an inch long.

Chucks for this spindle are made to fit the mandrel-nose. Wrought metal is generally used; and as the chucks are only small, steel may be employed without seriously affecting the exchequer. Rod material, three-quarter-inch diameter, is the most convenient. A stalk, three-quarters of an inch long, is first turned to accurately fit the plain part of the nose, which is seven-sixteenths-inch diameter. A thread is then cut on the stalk to within one-quarter of an inch of the shoulder. The whole is smoothed off, and the chuck should then fit the nose. The shoulder should be quite square to fit the flat face of the mandrel. The thread will be all the better for being slack, but the parallel cylindrical part should fit accurately. The projecting part of the chuck is fashioned to form according to the purposes for which it is required. It is scarcely necessary to detail the various forms of chucks which are useful for this apparatus. Those in general requisition are similar to some of those illustrated in a preceding chapter of this handbook.

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CHAPTER X.

MILLING AND PLANING ATTACHMENTS.

MILLING and Planing Machines are themselves the production of lathes. The former were used long ago for treating surfaces. Planers were invented fifty years ago, with the object of producing a machine that would do for straight surfaces what the lathe then did for round surfaces. Metal surfaces had been worked previously with milling-cutters, but apparently not with great success. Adaptations of these machines to be used on lathes have been often made. It is unnecessary to attempt to recapitulate the various contrivances that have been made to act with varying degrees of success. Manufacturers of lathes, and the various appliances used with them, have as yet done but little towards producing really serviceable attachments. There is here good scope for work, and I hope to see produced some cheap and useful milling and planing attachments, other than those illustrated in this handbook.

The value of "milling" appears to be but little known amongst a large portion of machinists. The milling machine, as now perfected, will do much work much better and much quicker than it can be done by any other process. In its particular sphere the milling machine is of universal application; in fact so much can be done with it that its uses are hard to define. Not only are flat surfaces treated, but mouldings may be milled with equal facility. By a proper adaptation of cutters, irregular surfaces may be produced and

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reproduced with the greatest ease. The milling machine acting automatically, always works to gauge, and thus duplicates standard sizes more accurately, and at a less cost than any other machine. The hand file, of course, cannot claim consideration in comparison with a milling machine. This

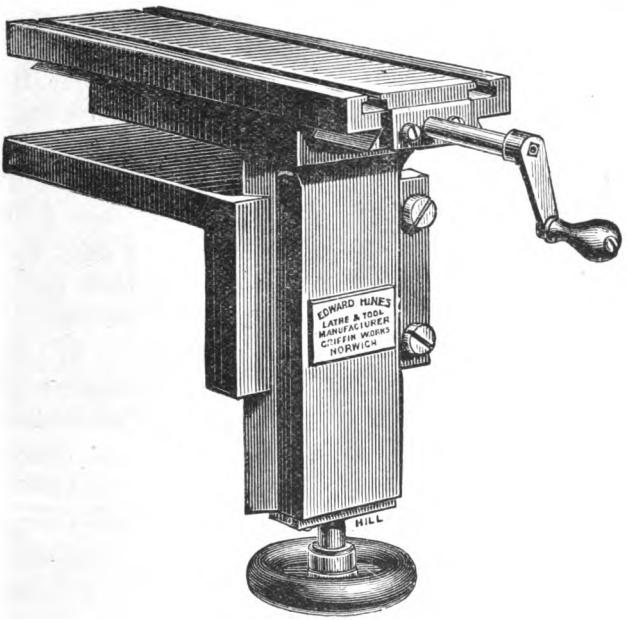

Fig. 68. HINES' MILLING ATTACHMENT.

has superseded the planer in many processes, and only requires to have its merits known to ensure an extended appreciation of its real value.

Milling, as practised on the lathe, usually consists in fixing a circular cutter on the mandrel nose by a suitable chuck; the slide-rest being used as a means of actuating the work to be operated upon. This simple plan is very limited in its application, a vertical adjustment being essential to most

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milling operations. By contriving an arrangement to fix the top slide of the ordinary slide-rest in a vertical position, much can be done with a cutter running on the mandrel nose. To describe how such arrangements have been contrived would occupy more space than I have at my disposal.

Fig. 63 shows a milling apparatus adapted for use on the lathe. Mr. Hines is the maker. It will be seen that the apparatus consists of a bracket, which is fixed to the lathe bed by an ordinary holding-down bolt. A dovetailed sliding piece, fitted on the front of this bracket, gives the means of vertical adjustment. The top part, forming the table, has ⊥ slots. These afford a hold for the heads of the bolts used to fix the work. The table is traversed to and fro by the winch handle shown. The cutter is fixed on the mandrel. In the apparatus illustrated there is no provision for any fine adjustment lengthways on the lathe bed. The apparatus has to be shifted by hand, and fixed by the holding-down bolt as nearly as possible to position. The maker says that this apparatus is adapted for milling slots and key grooves, fluting taps and reamers, finishing nuts and heads of bolts, cutting gear wheels, milling the cutters for use in conjunction with itself, besides an infinite variety of other work, which it will accomplish in far less time than any other machine tool. The apparatus illustrated costs £9 9s. The slotted table is twelve inches long, the transverse feed movement eight and

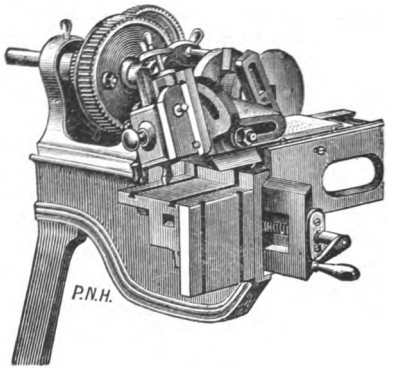

Fig. 64. BOOTHS' SHAPING ATTACHMENT

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a-half inches. The vertical slide has a range of three and a-half inches. An extra slide, giving adjustment parallel with the lathe bed, costs £2 extra. A more powerful apparatus than the one illustrated costs £12.

Fig. 64 is a shaping attachment, made by Messrs. Booth Bros. It is shown fixed on a four-inch centre lathe. The arm that carries the tool is fitted in a dovetailed slide at right angles to the lathe bed. The arm is actuated by a pin, placed eccentric in a catch-plate chuck. This pin, fitted with a block to increase the wearing surface, slides in a slotted arm, pivoted on a stud at the lower part of the attachment, near the surface of the lathe bed. The action of the eccentric pin produces a slow feed, and quick return motion, of the tool. The slotted arm swinging on the stud is connected with the tool arm by means of a connecting rod, one end of which is fitted to the bolt seen projecting from the horizontal slot in the tool arm. This slow feed and quick return motion is commonly adopted in large planers.

The table to which the work is attached has a vertical movement on the saddle of the horizontal slide, to which it is fixed by bolts. The slide fixed on the end of the tool arm is used to adjust the vertical position of the tool, after the table has been placed somewhere near the correct height. The horizontal slide, shown projecting on the front of the bed, gives the means of moving the work in a line with the lathe centres. The tool-box is of course hinged, to allow the tool to clear the work during the backward stroke. The slide carrying the tool-box is adjustable angularly, and it is shown much out of perpendicular. When the lathe is revolved, the arm carrying the tool is moved to and fro, the longest stroke being about three inches. The horizontal slide has a traverse of about seven inches; it is actuated by automatic feed from

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the mandrel. The pawl is shown projecting upwards at the far end of the leading-screw, the near end being provided with a winch-handle. This little attachment appears to be well designed, and it should be a useful apparatus.

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CHAPTER XI.

CIRCULAR CUTTERS.

CIRCULAR cutters are used to great advantage in many processes incidental to shaping metal. Their employment is termed milling; the operation being very similar to moulding and planing wood by machinery. During the past few years milling appliances have been greatly developed. Milling-machines are now used in machinists' shops where large numbers of pieces exactly alike have to be produced. Sewing-machines, fire-arms, and similar mechanism is mostly made by means of circular cutters. Regular or irregular surfaces may be treated equally well; and an important application of circular cutters is to cutting the teeth of gear-wheels. The great improvements recently made in grinding-machines, principally in the adaptation of emery-wheels, has conduced greatly to enlarge the sphere of utility of circular cutters. Milling-cutters can now be sharpened and kept in perfect order for work by simply grinding. Formerly it was necessary to soften the cutter, previous to sharpening with a file, and then to re-harden it.

Americans have done much towards perfecting labour-saving machinery, and the milling-machine is employed there to a far greater extent than it is here. An American mechanical journal recently published some remarks very pertinent to the subject, which I will here reproduce, and commend them to the consideration of our native machinists.

It is always a question of time for any machine, however

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perfect, to work its way into use in manufacturing establishments. We were reminded of this, a few days since, by observing that the proprietors of one of our young and enterprising machine-tool manufacturers are arranging to do with the milling-machine, in some instances, the entire work on certain sizes of machine tools, that has previously been done on the planer. They are satisfied that the work can be better done in this way—that with properly-constructed cutters the work of the milling-machine is done more accurately to standard size than is practicable with the planer; and they have demonstrated by actual trial that certain parts of the work, upon which planer-work has hitherto been thought indispensable, can be done with a milling-machine at a mere fraction of the cost. Many mechanics are impressed with the idea that the milling-machine is only adapted to the use of narrow cutters, thus precluding the possibility of operating upon surfaces of considerable extent by a single process. They might learn something to their advantage by witnessing the operation of some of the large, splendid tools of this class, designed for heavy work.

Another point upon which considerable misconception prevails is in relation to the durability of the cutters used with this machine. A very general opinion seems to be that the cutters are not only costly to make, but that they will last but a short time. In relation to the first of these ideas—the cost—with proper arrangements for making, the cutters are by no means so expensive to make as might be supposed. With reference to the second—the length of time they will last—those who are not familiar with their use would undoubtedly be greatly surprised were they to extend their observations in this respect. In point of fact, the facility with which the milling-cutter removes a large amount of metal, [illegible] operation on extended surfaces, does not

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render advisable a high speed. In other words, the large amount of work that can be got over by the use of the milling-machine is generally so satisfactory that there is little inducement to abuse the cutters by excessive speed. The most important feature in this respect is the fact that the direction of the cutter is such as to keep the cutting-edges almost literally out of contact with the scale or skin of the metal being operated upon. From this, and from the fact previously intimated—that there hardly exists the inducement to crowd the speed—the length of time that the cutters (which, of course, should be made of the best material) will last is remarkable. Another important feature of the milling-machine is the immense variety of work that may be done with one. With reference to this, it may almost be said that the greatest difficulty is to find what *cannot* be done with this tool.

That the use of the milling-machine is an efficient aid in assisting a shop to keep its work to standard sizes, especially such work as is somewhat irregular in form, is apparent. The ease with which irregular surfaces may, by a proper adaptation of cutters, be produced and reproduced, when compared with the tediousness and final uncertainty of other processes, not only cheapens production, but renders it easier to make any number of pieces alike than to make them unlike. On such work the milling-machine does its own gauging and measuring, and comes nearer, when required, to doing its own finishing than most other machine-tools. Taken altogether, it is a fact that a large percentage of mechanics have but little conception of the milling-machine in its present construction; and in many instances where it is in use, the variety of purposes for which it is available is by no means appreciated.

Various forms of circular cutters are illustrated by the

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accompanying engravings; these mostly represent cutters manufactured by Messrs. Brown and Sharpe (U.S.A.). The illustrations numbered Figs. 65 to 68 are milling-cutters, supplied by Messrs. Selig, Sonnenthal and Co. The prices

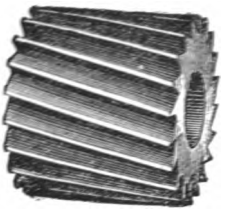

Fig. 65. CYLINDRICAL CUTTER.

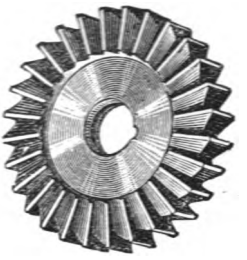

Fig. 66. CIRCULAR CUTTER WITH TEETH ON SIDES AND EDGE.

vary according to size, and I have considered it unnecessary to tabulate the prices as given in the catalogue. Fig. 65 is a cylindrical cutter, having the teeth cut in a spiral form; this is a decided improvement on the straight tooth. Fig 66 cuts on

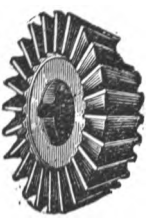

Fig. 67. ANGULAR CUTTER.

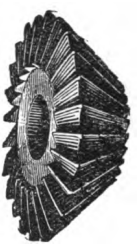

Fig. 68. ANGULAR CUTTER.

the edge and on both sides, so that it may be used for facing work, or in the manner of a circular saw. Figs. 67 and 68 are angular cutters, used for cutting the teeth of other cutters. They are made both right and left handed, and with various angles. These cutters can be sharpened without being softened. The operation can be repeated till the teeth are ground away,

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leaving the cutter almost blank. This, after being softened, can be re-cut and hardened, retaining its original form, but slightly reduced in diameter.

In the manufacture of small machinery many of the parts

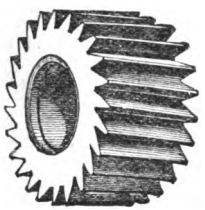

Fig. 69. PLAIN CIRCULAR CUTTER.

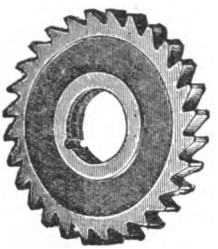

Fig. 70. NARROW CUTTER.

are of irregular outline, requiring expensive cutters to produce them. These cutters soon become dulled, and then require to be annealed, re-cut, and re-hardened at a cost nearly equal to new ones, while the steel of which they are made suffers injury

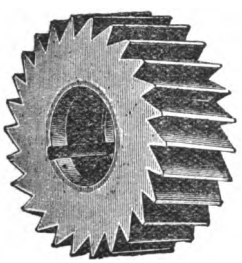

Fig. 71. CUTTER WITH SPIRAL TEETH.

Fig. 72. CUTTER FOR WHEEL TEETH.

from reheating, in the process of annealing and hardening. Messrs. Brown and Sharpe say:—"Those parties who have used our patent cutters avoid these difficulties as well as the expense attending them, and are able to produce better and more uniform work at less expense. Our cutters can be sharpened by grinding without changing their form. The

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method by which they are made also admits of exact reproduction of form in duplicating cutters. The operation of grinding can be repeated until the strength of the teeth becomes impaired, thus causing them to greatly outlast cutters produced in any other way. Parties having use for cutters of the above description can send us cutters such as they have been using, together with a correct outline, or a piece of work showing what is required, and we will produce patent cutters for the work."

Plain milling-cutters are shown by Figs. 69 to 71 and one for cutting gear-wheels by Fig. 72. These cutters are made in America by the firm previously mentioned, and by the Morse Twist Drill Co., and are sold by Messrs. Churchill and Co. Their catalogue contains tabulated lists of prices. Fig. 69 is a plain cutter made of various thicknesses, from one-eighth to one inch on the edge. Those of larger diameter, up to three inches, have the teeth cut spirally as shown in Fig. 65. Similar cutters, differing but little in their form and application, are shown by Figs. 70 and 71.

Fig. 72 shows a patent circular cutter used for cutting the teeth of gear-wheels. These cutters, which are stamped with the names of the manufacturers, are sold by Messrs. Churchill and Co. The following particulars are given :—"We desire to call the attention of machinists to our patent cutters for the teeth of gear-wheels, which, from their peculiar construction, can be sharpened when dull by grinding the faces of the teeth. This operation can be repeated without altering the form of the tooth which the cutter makes, thereby rendering them many times more valuable than cutters of ordinary form."

These cutters, for bevelled and worm-wheels, can be made to order at short notice. Orders should be given by stating the No. of cutter and the diametral pitch required. By diametral pitch is meant the number of teeth to the inch in diameter

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on pitch-circle of any required wheel. In ordering cutters for bevelled wheels give the largest diametral pitch, the number of teeth in each wheel, the length of face of teeth. In ordering cutters for worm-wheels, give the number of teeth in wheel, and diameter of worm, and number of threads to the inch. Eight cutters are made to each pitch, and they are numbered consecutively. No. 1 will cut wheels from one hundred and thirty-five teeth to a rack. No. 2, wheels from fifty-five to one hundred and thirty-four teeth. No. 3, thirty-five to fifty-four. No. 4, twenty-six to thirty-four. No. 5, twenty-one to twenty-five. No. 6, seventeen to twenty. No. 7, fourteen to sixteen. No. 8, twelve to fourteen.

The Pratt and Whitney Company (U.S.A.) give the following particulars on cutters for cutting the teeth of gear-wheels. The formation of teeth for gear-wheels has engaged the attention of mechanics and scientific men for many years. The conclusion generally reached has been that the sides of the teeth should be epicycloidal curves, generated so that all gears of the same pitch will run together. To accomplish this it has been demonstrated, by theory and practice, that all gears, to be interchangeable, must have their teeth formed by the same generating circle. Various methods have been resorted to, to correctly shape the cutter for cutting the teeth. Much labour and study has been given to the subject by the Pratt and Whitney Company, and the result is the invention and perfection of two machines; one, an epicycloidal milling-machine, by which it is possible to mill a perfect epicycloid. With this machine, large formers are made for use on a pantagraph machine, which delineates the exact shape of the former, and reduces it to any smaller pitch desired in the cutter. With these machines the Pratt and Whitney Company are prepared to make cutters for the market, and

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will quote prices on application. They say that the number of cutters required to cut from a pinion of twelve teeth to a straight rack, is twenty-four for each pitch.

The following directions for using circular-cutters are given by the makers. The cutters should be kept perfectly sharp by grinding the face of the teeth on the side of a solid emery or vulcanite wheel, which has its edge bevelled on one side so as to reach the bottom of the teeth. This wheel should be put on an arbor with a shoulder and nut, so that the flat side will run true, and at a velocity of from 2,000 to 3,000 revolutions per minute. If used in an ordinary foot-lathe, the top of the rest should be made square or vertical to the face of the wheel; or, what is better, use a small platform in the place of the rest. Then by laying the cutter on the rest or platform, the face of the teeth can be ground square, which is very important. The cutters should not be crowded too hard, especially when cutting through at the end of the tooth. The depth of the space made by these cutters should be as much more than is usually made as the amount taken to round the corner of the cutter, which is one-tenth of the thickness of the tooth on the pitch-line.

Few mechanics are familiar with the minute details of gearing, and the necessity of exact sizing of wheels is often overlooked. Two wheels gearing together must have their centres at a correct distance relative to the diameters. These points require, for their proper elucidation, more space than I can devote to them in this handbook.

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CHAPTER XII.

SLIDE-REST TOOLS AND CUTTER-BARS.

SLIDE-REST TOOLS are made in various forms to suit different work. Square bar steel is usually selected for making the tools. Cast-steel of special quality, adapted for the work, should always be used. For foot-lathes, from four to six inch centres, steel from half-inch to three-quarter-inch square is the usual range. The length may be varied from the form of the cutting end, but from five to seven inches is the average. The end of each bar is forged to some particular shape, and frequently both ends are so shaped, thus doubling the number of cutting-edges without increasing the number of tools. This plan cannot be adopted with tools that are cranked, unless the cranked parts of each end are made at right angles. Comb-screw tools may be made with the teeth at both ends, and also be used either side uppermost. Sets of slide-rest tools are sold by most of the tool-dealers, whose names will be found on another page.

The principles that govern the proper application of the tools appear to be very generally neglected in workshop practice. The slide-rest affords an inflexible hold for the tools; and with plenty of power almost any tool may be made to cut the material. Perhaps cutting is an erroneous term to apply to the terrible way in which some tools act on metal. A cutting-edge will penetrate best when it is thinnest; this is known perfectly well, and the knowledge is put into

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practice every day with innumerable contrivances. Thin edges cannot be adapted to all requirements, because they are not sufficiently strong. Thus, chisels used on metal must be thicker on the edge than is necessary for those used on wood. Thin edges, that is those which are most acute, cut best; thick edges, that is those which are obtuse, are strongest. A slide-rest tool for metal turning must be sufficiently sharp to cut, and sufficiently strong to withstand breakage.

An illustration herewith, borrowed from "Lathe-work,'

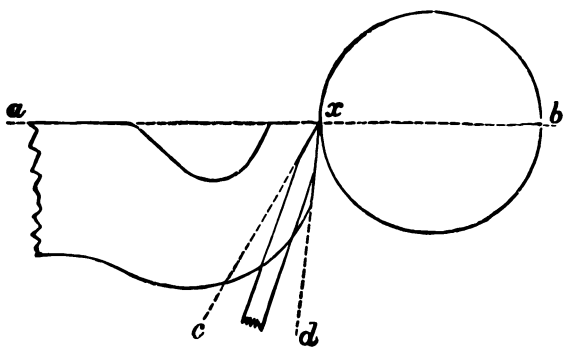

Fig. 73. CUTTING ANGLES OF TOOLS.

shows tools correctly applied for cutting both soft wood and hard metals. By this it is seen that the slide-rest tool, with a strong cutting-edge suited to dividing the cohesive metal, and the acute wood-turning chisel, each have the lower face angle placed in the same position with regard to the work. Therefore it is only the upper face which wedges back and curls or breaks off the shaving that is altered agreeable to the different nature of the material. The line of centres is shown in Fig. 73 dotted *a b*, and at precisely the height of this line should be the point of the tool fixed in the rest. Here it may be advisable to

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point out that tools must be packed up with parallel strips, otherwise the relative position of the angles is interfered with. The edge of the metal-turning tool is formed by the meeting of the faces *a x* and *d x*; *a x* being parallel with *a b*, and *d x* 3° from the perpendicular, gives the angle of the point as 87°. This is the most obtuse angle usually employed; though for some purposes where a scraping action is required the top face is bevelled off downwards to make the edge even more blunt. The edge of the soft-wood chisel is formed by the meeting of the faces *c x* and *d x*, enclosing 25°, still keeping the lower face situated precisely as before. The face of the tool *d x*, coming next to the work, requires to be ground at a slight inclination, leaving the point prominent to prevent the whole face touching the work, which by the friction would greatly increase the labour of turning. When this requirement is satisfied, the face should be as upright as possible, and 3° from the perpendicular suffices. The angles best suited for cutting metal are from 60° to 90°, varying in accordance with the hardness of the metal to be operated upon. The tools might be applied to any part of the circle, even vertically above it, so long as the same relative position is maintained; but the slide-rest as ordinarily constructed necessitates the application of the tool on a level with the centres.

Workshop slide-rest tools are frequently badly forged, badly ground, and badly applied. Cutter-bars offer many valuable advantages over solid tools, and should be adopted in preference. Many of the leading firms of engineers use cutter-bars throughout their works, with a most satisfactory result. Some of the most common forms for slide-rest tools are illustrated by the following figures. Fig. 74 is a roughing tool; this is a very simple tool to make. The end of the bar is somewhat flattened, pointed, and bent upwards. The

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cutting-point is rounded, and the upper face is usually ground with the lefth-and edge highest. This gives a prominence to the leading part of the edge when the tool is used for roughing plain cylindrical work in the usual direction, from right to left. Fig. 75 is a tool very similar in form and uses. It is a cranked roughing-tool, so called from the end being cranked downwards. The object of this is to place the point lower, and give more material for re-grinding.

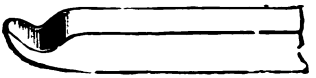

Fig. 74. ROUGHING-TOOL.

A V point roughing tool is shown by Fig. 76. The end of this tool is bent upwards, with a triangular top face. The front faces meet at an angle of about 120°, and the arris, which comes near the centre of the bar, is ground away, leaving a slight face about one-thirty-second of an inch wide. This treatment applies to all slide-rest tools, for if the acute arris is presented to the work, the edge becomes blunted immediately. A knife-tool is shown at Fig. 77. These tools are made in pairs, right and left handed. The end of the tool is forged to a narrow blade, the further side being ground flat; the top and end are bevelled off to form cutting edges. These tools are useful for finishing the ends of cylinders running between centres, as their form allows the point of the tool to reach the centre of the work against the poppet centre. Fig. 78 is a planisher used for finishing the surface of brass, and Fig. 79 is a similar tool, but cranked. A plain point tool

Fig. 75. CRANKED ROUGHING-TOOL.

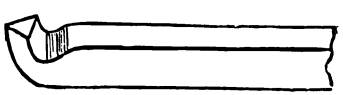

Fig. 76. POINT ROUGHING-TOOL.

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is shown at Fig. 80. This is, perhaps, the most simple of all slide-rest tools. The bar from which it is made is only drawn out slightly tapering, the end is ground to a V shape, and the tool is finished. If wanted to work right or left especially, the tool is bent as shown by the dotted plan, which represents a left-hand point-tool.

Fig. 77. KNIFE-TOOL.

The foregoing illustrations are given as representations of common workshop tools. They are in general use, but several much improved forms are shown in "Lathe-work." Tools of almost any shape will act, provided they have an edge of some sort; but a tool correctly formed has immeasurable advantages. Economy in power, expedition in production, and excellence of work, are all promoted by the employment of tools made on correct principles.

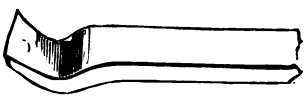

Fig. 78. PLANISHER.

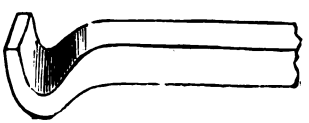

Fig. 79. CRANKED PLANISHER.

Cutter-bars are now largely used in preference to the solid tools. One shank serves to hold any number of cutters, and this is an advantage having many valuable points. Some of these have been pointed out in "Lathe-work. Two dozen cutters for a cutter-bar can be made from the same weight of material necessary to make one solid tool. This enormous economy in material conduces to the employment of the very best steel. When a tool of special form is

Fig. 80. POINT-TOOL.

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required a comparatively very small piece of metal has to be wrought, hardened and tempered. There is no direct advantage in using solid tools, and where cutter-bars have superseded them a considerable saving has invariably resulted.

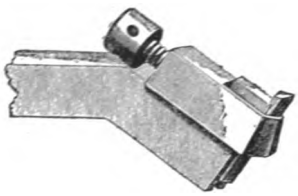

Fig. 81. HAYDON'S CUTTER-BAR.

One of the most useful cutter-bars for general outside turning is shown by Fig. 81. It is named, from the inventor, Haydon's cutter-bar. The Britannia Company manufacture these tools at various prices according to size. A half-inch bar, made of steel, costs 10*s.*; a three-quarter-inch bar, 12*s.* 6*d.* The cutters are made and sold ready for use for 6*d.* each, or they can be cut from square bar steel, of suitable size, and hardened for use.

An adaptation of the same bar is shown at Fig. 84; it is

Fig. 82. UNIVERSAL CUTTER-BAR.

made by Hines, of Norwich, and is called the "Universal." The jointed end to the bar affords a wide range of application of the same tool. Without removing from the rest, it can be fixed as a right or left hand tool, suitable for sliding and surfacing, and for cutting out angles upon either side. At all points it is firmly and rigidly secured by the clamping-nut, such combination making it equivalent to many ordinary tools.

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The application of a simple machine-made joint ensures that perfection of fit necessary to secure rigidity equal to a solid bar. It enables the tool to be readily adjusted to any desired angle up to 45° on either side of the centre line. This is invaluable in the execution of the variety of work that falls to the lot of the metal-turner of the present day, who uses a slide-rest tool for completely finishing all kinds of cylindrical

Fig. 83. OUTSIDE CUTTER-BAR.

work. This cutter-bar costs from £2 2*s.* to £2 10*s.*, according to size.

Tangyes have patented the three cutter-bars next illustrated. They are in use throughout the extensive works of the firm, who state that the result is a great saving. Steel is saved, and thus conduces to the employment of better quality. Time is saved by the mechanic, who can replace a blunt

Fig. 84. BORING-BAR.

cutter by a sharp one without leaving his lathe. Wages are saved, as no toolsmith nor striker is required.

Fig. 83 is a cutter-bar suitable for outside turning, screw cutting, &c. The head has three slots; the cutter may be placed in either, according to the work to be operated upon. As shown, the cutter projects to the left at an angle of 45° with the shank. The other two slots allow the cutter to be placed parallel with the shank, or at an angle of 45° to the right. The cutter is clamped by the screw shown on the

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top. These cutter-bars are made in various sizes, with shanks from three-eighths to two-and-a-quarter inches square; the former are suitable for lathes of three inches centre, and cost 9*s.*, the latter suit lathes twenty inches centre, and cost £2 5*s.* An internal cutter-bar for boring and screw-cutting is shown at Fig. 84. This has a mortise-hole at each end, one

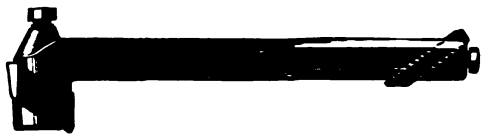

Fig. 85. COMBINED OUTSIDE AND BORING CUTTER-BAR.

diametrically across, the other at an angle. Clamp-screws at each end are used to fix the cutters. This cutter-bar costs from 8*s.* to £2, according to sizes, which are the same as those of Fig. 83.

Fig. 85 is a cutter-bar which combines the uses of the two last described. A glance will show that the shank, originally like Fig. 85, has the corners cut off for about half its length,

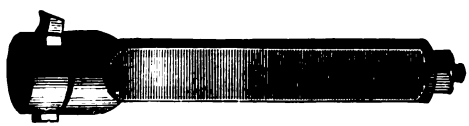

Fig. 86. TIMMS' INTERNAL TOOL-HOLDER.

and thus is made available for holding cutters for boring, as in Fig. 84. The prices of the cutter-bar, Fig. 87, range from 11*s.* to £2 10*s.* The cutters used with all these bars are very much varied in form and use. The prices range from 5*s.* to £5 per dozen; the former are plain cutters for the small bars, the latter complex cutters for the large bars. A box, containing a set of tools particularly useful for working at a foot-lathe, is sold at £4. The contents comprise a cutter-bar like Fig. [illegible], with half-inch shank; a set of sixty-four assorted cutters,

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including three screw-cutting tools for Whitworth's threads. Two extra clamp screws and a spanner are included. A similar outfit, with only twenty assorted cutters, costs £2 2*s*.

Fig. 86 shows a tool-holder, known as Timms' patent, used for boring. The cutter is placed diametrically across the holder; it is held in a shank which has a long tail passing completely

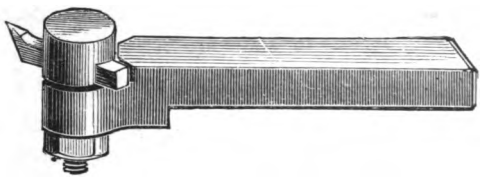

Fig. 87. TIMMS' EXTERNAL TOOL HOLDER.

through the square part of the tool. The shank is free to turn round, and so allows the cutter to be adjusted to any required height, where it is fixed by a turn of the nut on the end.

Fig. 87 shows a tool-holder for external work. It is similar to the tool last illustrated in the method of fixing the cutter, but the shank is placed vertical and is short.

Cutter-bars for boring, and other internal work, are shown at

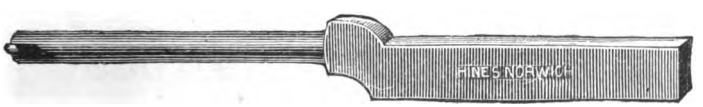

Fig. 88. "CLIMAX" CUTTER-BAR.

Figs. 88 and 89. The first is named the "Climax." The cutters fit into a mortise-hole cut obliquely in the end, so that the bottom of a hole may be turned out square. The cylindrical part of the bar is made in various sizes, to suit different diameters of bore; the price is 10*s*. 6d. The cutters cost 4*s*. per dozen.

The "Eclipse" internal cutter-bar is shown at Fig. 89. This consists of a bar of round steel, which slides through a square

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bar. This bar is slit on one of its sides, so that the pressure of the slide-rest clamping-screws causes it to grip the bar. This bar has the advantage of allowing the amount projecting to be regulated to suit the depth being bored. Thus the tool is

Fig. 89. "ECLIPSE" CUTTER-BAR.

made available for working in deep holes, without in any way affecting its rigidity for shallow holes. Mr. Hines considers it to be unquestionably the best internal cutter-bar in use. The bar costs from 15*s.* to 18*s.*; the cutters 4*s.* per dozen.

A cutter-bar for parting metal is shown at Fig. 90. The

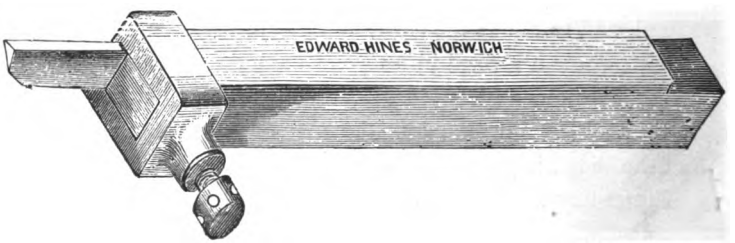

Fig. 90. PARTING CUTTER-BAR.

cutter consists of a strip of steel, which may be fixed at either end of the bar, so that it will be at the right or left side, as may be most convenient. The bar, complete as shown, with a shank nine-sixteenths of an inch square, costs £1 1*s.* Larger sizes are proportionately more costly.

Several useful cutter-bars are illustrated and described in "Lathe-work," to which treatise I refer those readers interested in these useful tools.

Tempering tools of various kinds is an art of great importance to every mechanic, practice being the most efficient instructor. A few hints will be serviceable. When heating

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steel be careful not to overheat it. A charcoal fire, or a Bunsen burner, are the best sources of heat. Steel must be hardened before it can be tempered. The hardening is effected by heating the metal to a bright cherry red, and immediately plunging it into cold water. Many mixtures have been recommended for hardening steel, but none are better than clean cold water. The sudden cooling of the steel makes it extremely hard and brittle, and for most purposes the temper must be drawn so that the tool will not break in use. The tempering is effected by heating the tool till the cutting-edge shows a change in colour, the depth of this colour indicating the degree of tempering. A surface of the tool to be tempered must be made bright and clean by grinding on the stone or with emery. The tool is then heated at a point behind the cutting-edge, in a smokeless flame. The heat will gradually change the colour of the bright surface; a faint yellow shows first, this deepens into brown, which is succeeded by purple, this changing to blue, and eventually to grey. As the change in the colour progresses the steel becomes softer, and hence a knowledge of the correct temper for various tools is necessary. When the tool has attained the correct degree of heat it is plunged into cold water, and all further tempering at once arrested. Tools for metal turning are usually tempered to some shade of yellow, but the quality of the steel will greatly affect the ultimate result. Many tools are hardened and tempered at a single operation. The steel is heated and the point only plunged into water; the tool is then withdrawn and the heat in the shank draws the temper. This method is only practicable after long experience, and it is not to be commended.

Case hardening, a process by which iron has a steel-like skin imparted to it, usually involves the use of a certain plant which need not be enumerated here. The following method

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can be practised in an ordinary fire, and frequently effects all requirements. The iron article to be hardened is heated to a bright red, and then covered with powdered prussiate of potash. The hot iron will fuse the potash, a covering of which will adhere. The iron is again heated to redness, and again covered with potash. These operations may be repeated several times, or only once, according to the depth of hardness required. The hardening is finally effected by heating the iron to a bright red, and immediately plunging it into cold water. The surface will then be as hard as hardened steel. By these means, many tools required only for an odd job may be made of iron, and be equally good as steel. The liability to crack and flaw in hardening, to which steel articles are subject, is also avoided by using iron, but these latter tools will not stand much grinding.

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CHAPTER XIII.

TOOL GRINDING.

EDGE-TOOLS are employed in many mechanical operations; keen edges, properly shaped, always give the best results, so that all those who employ edge-tools will find tool-grinding a subject deserving close study. Grindstones of various sizes, forms and textures, are employed for grinding and shaping edge-tools. A flat circular disc of sandstone, or sandstone grit, has been used for sharpening in generations past. The ancient warrior put an edge to his bronze spear-head by the means employed by the modern cutler to give the keen edge to a razor.

Probably no workshop tool pays better for the care bestowed upon it, or affects the work of an entire factory more, than the grindstone. It is, however, almost an exceptional occurrence to find a good stone, properly hung, running true and in perfect order. The workshop stone generally has a trough beneath it to hold the water. Being left with a portion of its edge immersed, that part becomes softened, and the stone wears unevenly. The out-of-doors grindstone soon becomes a worthless wreck from the effects of the weather; the sun's rays warping the wooden frame, and making the stone itself too hard for use.

Although the applications of a grindstone are limited, still, in its sphere it acts to perfection. No machine or process has yet been devised to supersede the grindstone, and improvement has added but little to this primitive tool. Science has

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produced artificial compounds which take the place of the original natural stone; and they are often used advantageously. They are, however, new only in the method of manufacture. Emery compounds are now used very extensively for all purposes of grinding, and they have many advantages over the natural stones. Probably the employment of emery grinders will become universal at an early date. Even now they are fast displacing natural stones in Government workshops, and other large factories where economy is studied.

Every employer of edge-tools should endeavour to get a grindstone that will do its allotted work well, and in the quickest time. A good grindstone, to replace one that is hard and flinty, is always a paying investment. A writer on the economic conduct of workshops recommends that a bad stone should be immediately broken up as the best means of saving time and trouble, besides earning the thanks of those who would otherwise have to use it. Only those who have used a good stone, properly mounted, with its edge running perfectly true, can appreciate the worth of a grindstone. Those who have used only lumpy, badly-kept stones cannot form a just estimate of the value of grindstones, as applied to the production of the edges of hardened steel tools. The requisites of a good grindstone are uniformity of texture, a keen bite, freedom from cracks and flaws, and sufficient cohesion to hold together and withstand the enormous centrifugal force to which it is often subjected. Newcastle stones are widely known and excellent. They vary in their texture, and coarse or fine grit may be chosen as desired. Artificial stones are made by binding together silicious particles with silicate of lime. According to the fineness of the grains of sand used, the texture of the stone is modified; or emery may be used in its stead, resulting in a grindstone of very good qualities.

The grindstone for general purposes, as required in the

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workshop of a metal-turner, should be at least eighteen inches in diameter, though two feet is a better size. It is then large enough to form its own fly-wheel, the stone being mounted in a frame of its own. A treadle is far preferable to a hand-winch for turning the stone, as the latter generally necessitates the service of two persons to grind. Even the most simple tool, as a rule, requires the use of both hands to guide it on

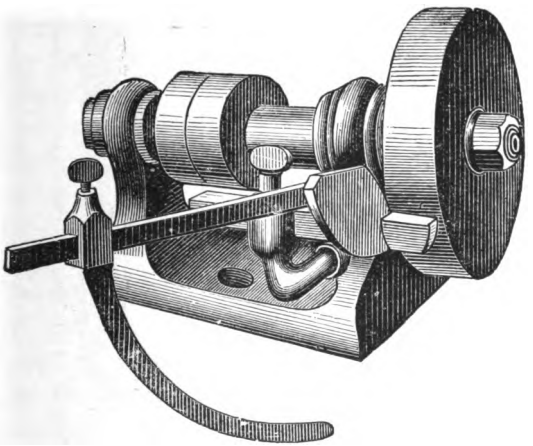

Fig. 91. MORSE'S DRILL GRINDING MACHINE

the stone. When an attempt is made to turn the winch by one hand, and hold the tool by the other, unsatisfactory results are obtained. For ordinary tool-grinding, sufficient speed is got by turning a two-feet stone as fast as convenient by a treadle. With a hand-winch the speed is much too slow. When steam-power is used to drive, a surface velocity of three to four miles per minute is sometimes attained for special purposes. Ransome's patent free-grit stones, made by the method previously mentioned, are asserted to have a tensile strength of about six hundred pounds per square inch, and the

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best results are attained with a surface velocity of from two to four thousand feet per minute.

For grinding the twist-drills, now so generally used in

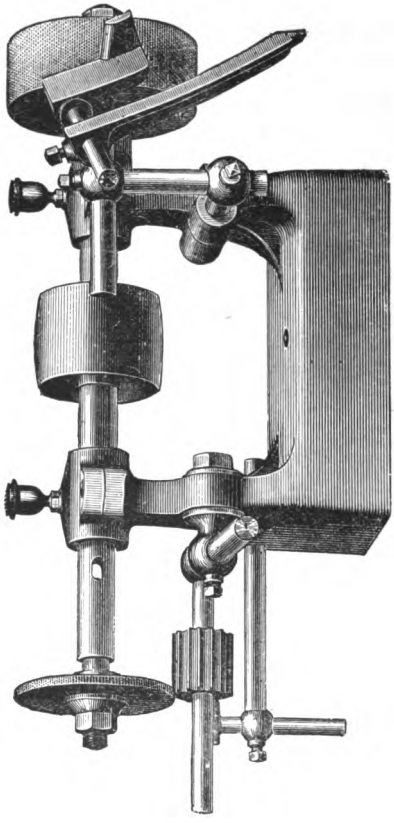

Fig. 92. Morse's Drill and Cutter Grinding Machine.

machine shops, special machines are frequently employed. Twist-drills are so eminently superior to the old-fashioned shape, that consequently, when the first cost is not an insurmountable obstacle, the newer form of drill is used. The Morse Twist Drill and Machine Co. now manufacture two sizes of

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machine. Messrs. Churchill & Co. import them, and the accompanying illustrations show their forms. Fig. 91 shows a machine for grinding any drills under half an inch in diameter. The price is £2 1*s.* 6*d.* The larger machine is constructed for grinding drills from three-eighths to two inches in diameter. The price is £6 5*s.* The illustration, Fig. 92, shows this machine also adapted for grinding the circular cutters used for milling. This machine costs £8 15*s.* complete. The emery wheels are extra. It may not be superfluous to point out that these drill-grinding machines may be used as emery grinders for various other purposes.

Emery-wheels are now manufactured in large quantities and retailed by shopkeepers throughout the kingdom. Grains of emery are consolidated into wheels of all sizes and forms, and a simple simile of their use is that the emery-wheel is to the file what the circular-saw is to the hand-saw. It is a rotary file whose cutting-points never grow dull. Emery-wheels used as files will, in one minute, do work equivalent to that produced by file-strokes a mile long. In other words the emery-wheel will do in one minute work that would employ a filer over one hour. Emery-cloth is also largely used for grinding purposes, and, stretched over a flat surface, it will finish a surface better than a file.

The cutting-edge of any tool is formed at the union of two facets making the point of a wedge. Considerations of strength determine the angle at which these facets meet. The thinner the cutting-edge the better it will act, providing no strength is required. A lancet or razor requires but little strength, and hence these instruments are made with thin edges. A metal-shearing machine requires great strength, and consequently the edges of the cutters are thick. When tools are ground the operation should always be conducted on scientific principles, so as to produce the best results. The application of the tool

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to the work must also be correct. A properly-shaped tool, improperly applied, will probably not be more effective than one applied on correct principles, having a badly formed edge. Well-ground tools, properly applied, are the essentials of economic workshop practice.

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CHAPTER XIV.

SUPPLEMENTARY ITEMS.

SEVERAL machines and tools, which have been excluded from the early part of the book, form the subject of this chapter.

Fig. 93 shows a lathe possessing many unique features. It is the production of G. Birch & Co., of Manchester, a firm which is turning out some remarkably fine work. Lathes and tools for amateur and high-class users are their specialty. The lathe illustrated is constructed for ornamental turning of most delicate and intricate nature and also for operating on heavy metal work. The lathe is five-and-a-half inch centres, with cast-iron bed and standards, a steel guide-screw the full length of the bed. The crank has an adjustable throw; and the steel shaft runs in universal bearings, which adjust themselves to the spring of the crank-shaft, causing the lathe to be very easy running and free from the usual tremor. These bearings are a new feature in lathes.

The fast headstock is double-geared with machine-cut wheels. The mandrel is tubular, thereby allowing rods to pass through. The division-plate is marked and figured to read at sight so as to obviate counting, which is often a great nuisance in fine dividing; an additional interpolating index is fitted to read to thousandths of an inch. In addition to these appliances for dividing, the mandrel has a worm-wheel, and by means of finely-cut change-wheels on the tangent screw any division may be readily obtained with absolute certainty. A

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segment engine with stops is also attached. The back gear spindle is a duplicate mandrel with nose, &c., and thus forms a

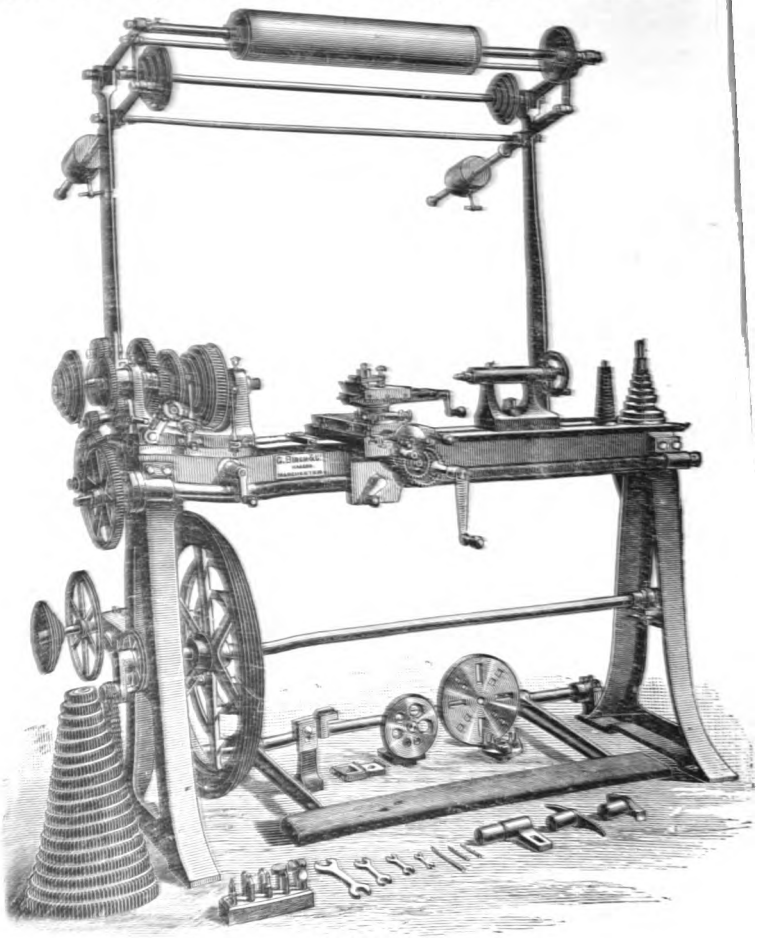

Fig. 93. BIRCH & CO.'S NEW LATHE.

perfect medallion cutter, rose engine, and copying lathe, on the principle invented by Mr. Jesse Lowe. At the back end of the

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mandrel a set of reversing wheels is arranged for readily changing the direction of the travel of the carriage, as in cutting right or left handed screws. An improved catch arrangement holds these wheels in or out of gear as required.

The poppet-headstock is fitted on a saddle, allowing the centre to be set out of line for taper turning. Divisions on the base show the amount that the centre is thrown out. The boss of the hand-wheel carries an adjustable sleeve for indicating the exact advance of the centre, forming a gauge in drilling, &c. These adjustable micrometer indicators have been in use for many years by the maker of this lathe, and also by myself; they have recently been adopted by others.

The slide-rest is fitted on a carriage which travels the entire length of the bed, having a gun-metal clasp-nut to gear with the guide-screw. Self-acting surfacing motion is also obtained by a worm-wheel on the inner end of the shaft that takes the quick traversing handle. The guide-screw may be operated slowly and to the greatest nicety for dividing, by means of a worm-wheel, actuated by the tangent screw which forms the axis of the handle just below the fast headstock, forming a micrometer showing exact distances moved by the carriage. Slots of ⊥ shape are milled out of the carriage, so as to afford means of bolting down work or apparatus.

The upper part of the slide-rest slides back right off the carriage without necessitating any unscrewing. The leading screw of the cross slide has an adjustable micrometer reading to thousandths and to binary divisions of an inch. It has also an efficient quick withdrawal motion with Birch's improved self-acting arrangement for releasing and locking by one movement. The top slide fits into a socket and has a graduated base and an elevating nut for adjusting the height of the tool. Stops are provided to allow the slide to be replaced at any required angle.

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The slow motion required for medallion and rose engine turning is obtained by the spindle shown fitted to a bracket projecting from the left-hand standard. This spindle is driven from the small grooved wheel on the crank shaft and drives the back gear spindle by means of a gut-band connecting the pair of four-step pulleys shown. The back gear spindle conveys motion to the mandrel by means of change-wheels, which may be proportioned to produce simultaneous or different rates of rotation.

The overhead gearing is supported by a pair of oval sectioned standards. The arrangement of levers shown produces an equal motion at both ends, so keeping the drum parallel with the lathe centres. This new arrangement is an improvement that will be readily appreciated. A quadrant, not shown, allows the overhead to be locked in any position. The drum is provided with a frictional clutch arrangement at each end, so that, by loosening the milled collars shown in the illustration the drum may be shifted along its shaft to any desired position. The ends of the drum have V-grooved metal pulleys, and by the aid of these very heavy wheel cutting, &c., can be accomplished with suitable apparatus.

The usual appurtenances accompany the lathe. They are shown in the illustration Fig. 93. The entire lathe is got up in a thoroughly workmanlike style. All surface bearings carefully scraped to fit. The wheel-teeth are cut from the solid metal; all graduations accurately divided by machine. The lathe is, as a whole, well worthy the careful study of all who are interested in high-class machinery, and reflects great credit on the enterprising young firm that has produced a carefully thought-out machine untrammelled with the incubus of tradition.

The illustration, Fig. 94, shows a new Gear-cutter, made by the Britannia Company, which can be fitted upon the slide-rest of any lathe, and the cross and parallel slides are thus

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utilised to give the necessary traverse; or it can also be fixed upon a tool-post. It is driven from an overhead pulley. The circular cutters are held on the spindle by the nut and washer. A vertical slide, actuated by a handle fitted to the vertical spindle, shown broken off, gives the necessary vertical traverse. This is a most useful adjunct to the lathe for fluting taps, milling key ways, spiral fluting, cutting spur,

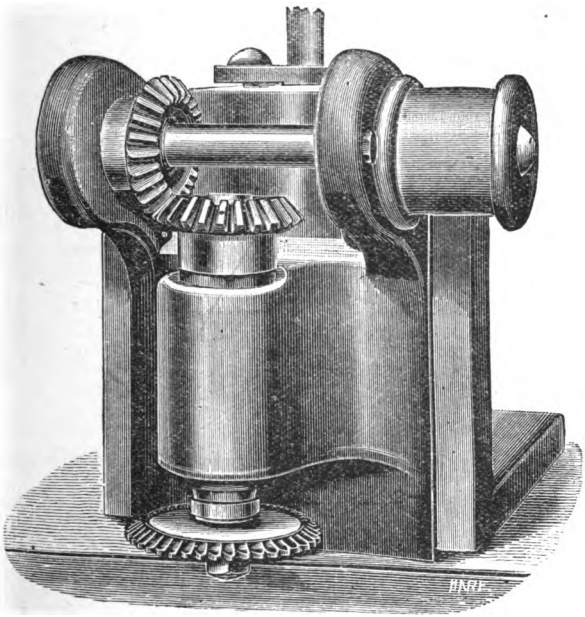

Fig. 94. BRITANNIA CO.'S GEAR CUTTER.

bevel and worm wheels, &c. Wheels with any number of teeth can be accurately cut by aid of a division-plate. The price is £4 4*s*., adapted for lathes up to 6-in. centres.

Fig. 95 illustrates a flange-mandrel particularly adapted for repetition work, the mandrel being intended to remain fixed to a face-chuck which screws direct on the mandrel. It is made

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by H. B. Barlow and Co., of Manchester; and the object of the inventors was to overcome the disadvantages and loss caused by driving solid mandrels into wheels and other pieces to be turned. To accomplish this they make that part of the mandrel which holds the work in three pieces, which expand accurately parallel and thus give a thorough hold without injury to the work. Holes of various sizes can be gripped on

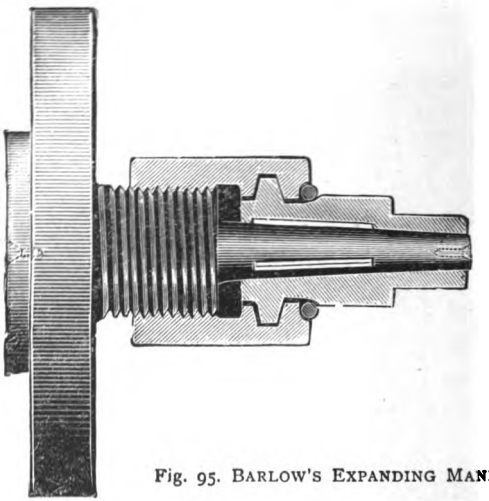

Fig. 95. BARLOW'S EXPANDING MANDREL.

the same mandrel, by using the different split bushes supplied. A good expanding mandrel has many recommendations, particularly to amateurs, as it holds delicate work by the bore without necessitating a special sized hole. The mandrels are, I am informed, in extensive use, especially around Manchester, and a silver medal was awarded to them at the Inventions Exhibition last year.

Noble's expanding mandrel, made by the Britannia Company, is shown at Fig. 96. The explanations given on the illustration show the construction and use of the mandrel. The mandrel has three grooves in which the steel slides, F, fit;

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these slides expand automatically and parallel, and a heavy cut tends to further tighten the hold. These mandrels are made in eight sizes, the smallest, taking 1¼-in. bore, costs 35*s.*,

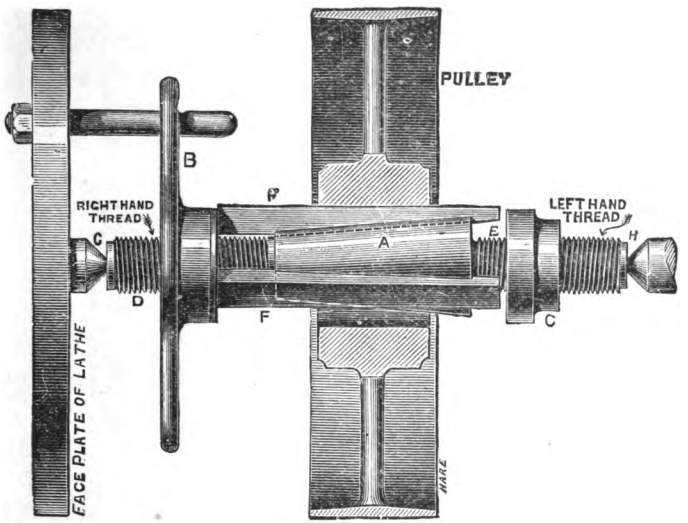

Fig. 96. NOBLE'S EXPANDING MANDREL.

and the largest, taking 5½-in. bore, costs £5 10*s.*, each having a range of from ¼-in. to ⅝-in., according to size.

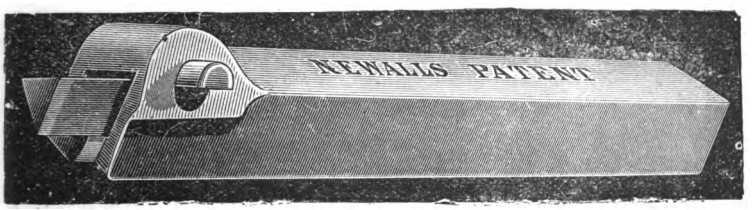

Fig. 97. THE "ONGAR" TOOL BAR.

The "Ongar" tool-bar is the name given to the slide-rest tool shown at Fig. 97. This tool-holder has a peculiar feature of very great importance—there is no overhanging part. The bottom can rest its whole length on the top of the slide-rest,

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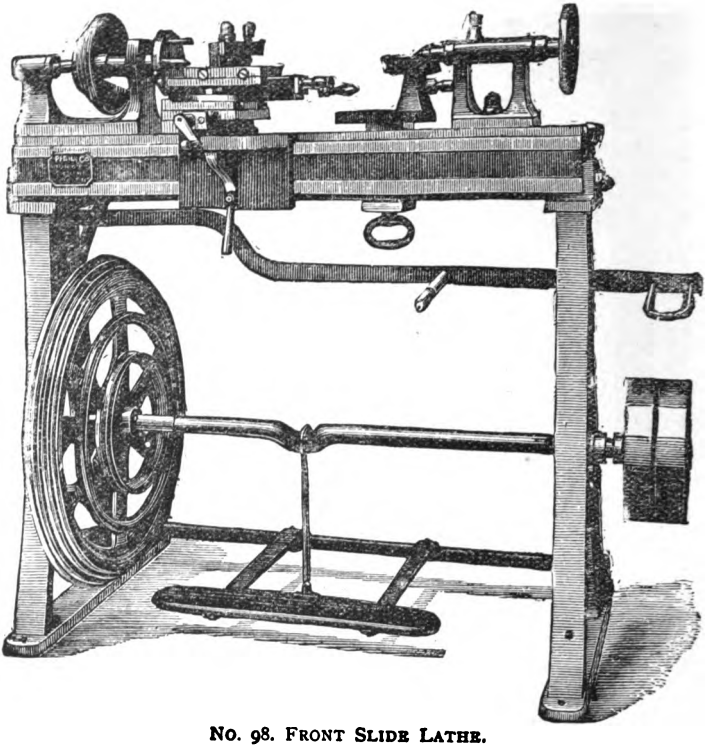
and the tool itself merely projects a distance equal to the depth of the cut to be taken. The cutters are made of triangular bar steel and pass right through the shank. No smithing is required and the cutter is fixed so that its leading



No. 98. Front Slide Lathe.

faces have just enough angle of clearance. The section of the bar gives the angle of 60°, which is well suited for steel and iron; all the grinding is done at the end of the cutter. Right and left hand bars are made and a screw can be used for [illegible]ing the cutter, in place of the wedge shown.

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A lathe having a slide along the front of the bed is shown at Fig. 98. The special feature of this lathe is that the slide-rest can be slid along the bed past the poppet head, without entirely detaching. The slide-rest is clamped to the front of the bed by means of the lever handle shown. The handle of the cross slide may be used on either end of the slide-rest screw, and for internal work it is often found convenient to put the handle on the far side of the rest, and to turn it with the right hand. Thus the workman may lean over the lathe and get a good view of the tool at work. The lathe illustrated is $4\frac{1}{2}$ inches centres, and the bed 3 ft. 6 inches long. An arrangement is shown for readily adapting the lathe to be driven either by foot or by power. For the latter, a belt from the main shafting would pass over the pulleys on the right hand end of the crank-shaft and would be shifted by the belt-striker shown under the bed. When the belt is on the loose pulley, the lathe is available for working by foot. Messrs. Pfeil and Co. call this lathe "The Electrician." and charge £19 10*s.* for it.

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CHAPTER XV.

LATHE MOTORS.

MOTORS, actuated by steam, gas, water and air, are largely used for driving lathes. Large flying-wheels turned by hand, formerly much used, are now but rarely met with. Steam is the motive power that is pre-eminent in large factories, but various small gas-engines are now used in factories of less extent. Owing to the importance of the subject of economising labour, I have deemed it advisable to devote a chapter to lathe motors, even in this manual, which professedly treats of the foot lathe only. Mechanical motors have become the source of driving by far the largest number of lathes used in the various industries. The cheapness of the power is its chief recommendation, and is the one that commends it to manufacturers.

Foot power possesses advantages for many operations, and it cannot be entirely superseded by mechanical power. When driving with his own muscles the turner has complete control over the machine he works. The various speeds requisite for various operations are regulated intuitively by the practised workman. For treating delicate work this power is essential. When turning becomes an almost automatic process, a mechanical motor is cheaper and more effective. In an early chapter some remarks bearing on this subject will be found. The following illustrations and particulars are given with the object of affording a means of comparing the different points of some motors suited for driving lathes, &c.

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Hindley and Co. have produced some steam engines that are particularly suited to the purposes above mentioned. The engines are well-proportioned, the bearings are long, and fit in gun metal journals. The governor is constructed to ensure a uniform speed under varying work.

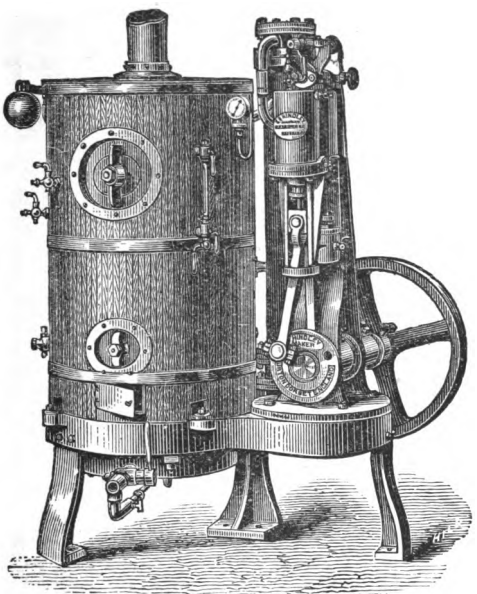

FIG. 99. STEAM ENGINE TO BURN GAS FUEL.

The steam-engine, shown at Fig. 99, is constructed to burn gas as fuel, and thus offers many valuable advantages to those who stop and start work at irregular or frequent intervals. These engines are lighted instantly, they require very little attention, and make no smoke, dust or dirt. The price varies from £40 for a half-horse power to £130 for a four-horse power. The illustration shows the various details of construction very plainly.

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Gas engines have now become very generally useful. They may be started instantly at full power, and stopped with equal facility. They do not need constant attention, and are from

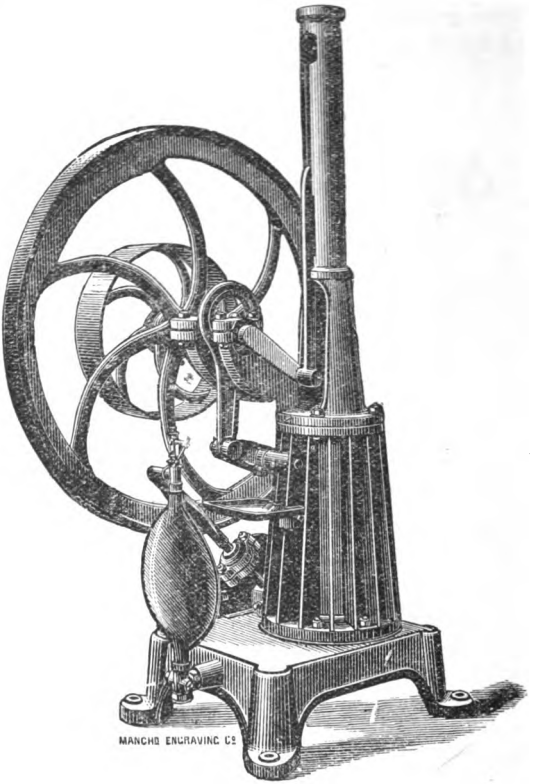

FIG. 100. BISCHOP GAS ENGINE.

many causes, the cheapest motor for working. To explain the principles and discuss the merits of the various gas engines now in the market, does not come within the scope of this handbook. The accompanying illustrations show some of the most useful engines made. The particulars given with each

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will suffice to enable the reader to infer something as to cost, capabilities, and expense of working.

The "Bisschop" engine, is shown by Fig. 100. The popularity of this engine is evinced by the large sale it has had, and the effectiveness with which it will perform various work, incidental to metal turning is proved by the testimony of those who use it. The prices of the engine, which is made in four sizes, are: one-man power, £25; one-and-a-half-man, £30; two-man, £35; four-man, £50. The cost for gas to work these engines to their full power is ½*d.*, *d.*, ¾*d.*, and 1½*d*, per hour respectively. I cannot do better than quote from the testimony of those who have "Bisschop" engines in constant use, in order to show their merits. One engine drives a five-inch centre lathe, easily taking a three-sixteenth cut off inch-and-a-half wrought iron. Another, driving a six-inch surfacing and screw-cutting lathe, takes three-sixteenths off three-inch wrought iron. Another, one-man-and-a-half power drives a six-inch Whitworth lathe, and also a grindstone; the owner an amateur turner, being very pleased with its performance. The makers issue a pamphlet in which are printed numerous testimonials, which afford very interesting information on the uses to which the "Bisschop" engine has been applied.

The "Otto" gas engine has achieved a reputation which gives it a pre-eminent position. Fig. 101 shows the pattern of these engines. The price begins at £60, for a half-horse power (nominal); this engine weighs about twelve cwt., and will indicate over one-horse power. Other sizes are made up to sixteen-horse (nominal), price £350, this engine indicating from thirty-six to forty-horse power. The consumption of gas by these engines, when in good order, may be taken at from eighteen cubic feet of gas per indicated horse power per hour for the sixteen-horse power, to twenty-five feet for the half-horse power, the larger sizes using less in proportion than the

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smaller. This assumes the engine to be working up to its maximum power. The consumption of gas in practice will however, depend on the amount of work done by the engine.

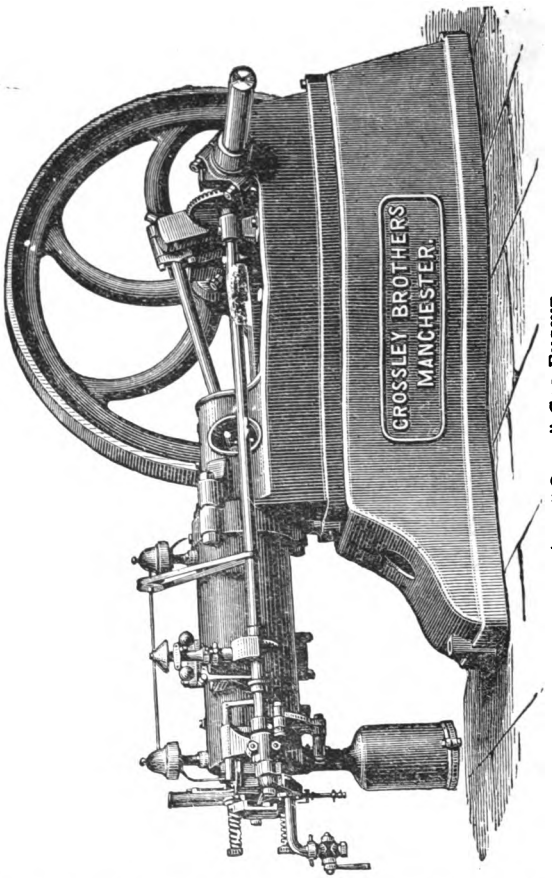

FIG. 101. "OTTO" GAS ENGINE.

At intermittent hoisting work the consumption of gas is sometimes as low as 10*d.* per day for a three-and-a-half-horse power engine, with gas at 4*s.* per thousand feet, and the engine running all day.

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The principle of combustion in this gas engine is entirely new. In it an explosion does not take place in the ordinary meaning of the term. A small part only of the charge is combustible, which on ignition serves to expand the remainder, thus avoiding shock and effecting great economy. The engine has also the peculiarity of igniting its charge at the *beginning* of the stroke, leaving the whole of the stroke for effective expansion of the gasses. Every part of these engines is made to gauge, and is, therefore, easily replaced. The wearing portions are also of the simplest and most inexpensive patterns: for instance, the working barrel of the cylinder itself can be supplied for about one-and-a-quarter per cent. on the first cost of the engine; and being strictly to gauge, can be put on in a few hours. The pistons are of great length—of which the peculiar construction of the engines readily admits, and being also as light as possible, ride on the oil with the least degree of wear. They have now run for years without repair. The slide valves keep in excellent condition with proper care; but as far as possible, to prevent risk of stoppage even through neglect, they are supplied in duplicate with each engine, except with the half-horse power size, without extra charge. They have been much improved by an arrangement under a recent patent. These engines will run with extreme smoothness and regularity of speed, and have very few working parts.

A small hot air engine shown at Fig. 102, is manufactured by Messrs. Bailey. This little motor is called the "Bee;" the price is £15, a larger size, £20. The "Bee" is driven at a cost of one farthing per hour, by a gas-jet with a Bunsen burner. It can be taken apart and cleaned by a boy without fear of derangement.

The engine consists mainly of a cylinder, one end of which is within the stove, and the other surrounded by a water casing. It is kept at work by the alternate heating and cool-

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ing of the air within the cylinder at every revolution, and requires no attention beyond the oiling of its working parts every three or four hours.

FIG. 102. "BEE" MOTOR.

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CHAPTER XVI.

MISCELLANEOUS ITEMS.

MANY items of interest to the metal turner could not be included under the headings of the previous chapters. Useful notes of the most varied nature will, however, be appropriate here. The lathe and its various appliances continually require adjustment and attention, other than that comprised in the work of the turner. Those who work at a foot-lathe have to carry out many processes which have not been mentioned in this manual, though they are inseparable from lathe-work. Miscellaneous items incidental to metal turning would occupy an almost limitless space, so only some of the more important can be introduced here.

Lubrication is a subject that has many features of interest to those working at a lathe. The machine itself must be lubricated, and the cutting tool should also be lubricated. Messrs. J. Veitch Wilson & Co., of Glasgow, oil manufacturers and refiners, publish some valuable information on lubricating oils. The firm will send any of their published pamphlets free of cost, and they are well worth careful perusal by those interested. Sperm oil, olive oil, and others have many advocates, but oil specially manufactured for the use to which it is to be applied is the best. Oils of different kinds possess different qualities, and, if these are duly considered and judiciously combined by admixture, the most satisfactory result is attained.

Lubricating liquids for turning are various; soapsuds are

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perhaps in most general use. The addition of oil is an improvement, any waste will serve the purpose, soda should always be added, it allays the rusting tendency of the water. Wrought iron and steel should always be lubricated when turning, the work proceeds faster, the tool cuts better and will last longer, and less power will drive the lathe. A reservoir to contain the lubricant should be provided, and by means of a spout the fluid can be directed to any part. It should always fall on the work at the point where the tool cuts. A tray should be provided beneath to catch the lubricant, which may be re-used many times. When the slide-rest travels along the bed, as in

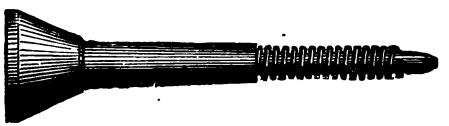

FIG. 103.—BELL CENTRE PUNCH.

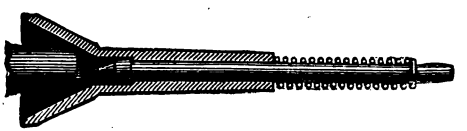

FIG. 104.—SECTION OF BELL CENTRE PUNCH.

screw-cutting, the reservoir should be fixed to, and travel with the rest. For some purposes petroleum is a very good lubricant, and pure oil is excellent, but too expensive for general use.

A useful tool for centring all forms of rod metal is shown by Figs. 103 and 104. The first is an elevation, the second a sectional view showing construction. The tool consists of a steel centre punch, fitted in a gunmetal guide which has a cone shaped mouth. A spiral spring keeps the punch at the apex of the cone. When using this tool, the cone is placed over the work to be centred, as shown in Fig. 104, and, by a light blow from a hammer, the point of the punch indents a centre mark.

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This mark is deepened subsequently by means of an ordinary centre punch. Several sizes of bell punches are made to suit rod metal of various dimensions. Regular polygons can also be centred with it. I have successfully used in constant practice a punch of the above description, which was supplied to me by Messrs. Booth Bros. The end of the rod to be centred has to be made tolerably flat, and the punch must be applied upright to ensure success.

Speed for turning and rate of feed are subjects that should have been determined long ago, but Mr. Northcott thus facetiously treats these topics in his "Lathes and Turning." "The practice in the matter of speeds varies somewhat in different workshops and with different workmen. The usual speed cannot be ascertained with certainty by calculating the speed at which a certain workman drives his lathe, nor even by taking the average of a good number of workmen. The average speed in large workshops will generally be under the average speed in small establishments. In other words, the average speed in establishments overlooked by the master will usually be found above that of establishments overlooked by a foreman. Another more remarkable fact is, that the speed in hot weather will often be less than the speed in cold weather. The power required to drive a lathe and the speed at which it should be driven are points worth serious consideration, but very little attention is usually given to them. Most workmen, who habitually use power-lathes, would profit by a few months' work at a foot-lathe. With the best tools the work is rather tiring; but with badly shaped tools the work is still more laborious. The difference is readily perceivable by the workman driving the lathe, and there is a weighty reason for using properly shaped tools."

On enquiry in large turning shops as to the speed adopted, I have been much surprised to learn that the subject receives

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but little attention. Each turner works at whatever speed he may choose, and that is generally just where the driving band may act with the least trouble. The only facts that I can commend are based on experiments made with slide-rest tools, made of the best steel and untempered after hardening. Wrought-iron shafting was turned at a speed of fully forty feet per minute, the feed being one-sixteenth of an inch. Sixteen feet of shafting, two and a-half inches in diameter, may be turned at this rate in a hour. The following rates of speed are recommended. Supposing the work to be one inch in diameter the number of revolutions per minute should be: Brass, four hundred and fifty; cast iron, one hundred and forty five · wrought iron, one hundred and thirty-five; steel, seventy-five. The same materials, three inches in diameter, should be turned at one hundred, forty-five, thirty, and twenty-five feet per minute respectively. These speeds are for average work on average materials, using the best tools in the slide-rest. For hand turning the speeds may be increased considerably, as in this case the tools are withdrawn so frequently. It is evident that some systematic experiments are necessary to determine the speeds that are most economical, and it would afford me much satisfaction to see the results published.

Since the above was written, Professor R. H. Smith has published, in his manual on "Cutting-Tools worked by Hand and Machine," the results of some very interesting experiments with cutting-tools used in the lathe. The observations he made are so particularly appropriate here, that I am constrained to reproduce them as fully as possible. Plotted diagrams are given showing curves co-ordinating the cutting forces under various depths of cuts and various widths of shavings in cast iron, in wrought iron and in steel; these serve to graphically illustrate the results of the experiments. With but slight alterations the context is as follows :—

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The cutting force required in lathes varies rapidly with the depth and breadth of shaving turned off. One large portion of the power consumed by a lathe is expended in overcoming the friction of the bearings, in bending the belts or bands whose stiffness resists their motion round the pulleys, and in driving the traversing gear of the slide-rest. The chief point of scientific interest, is to discover that part of the power actually spent in the removal of the shaving. A series of experiments were carried out by Professor Smith to find out how this power varies with the depth of cut, with the breadth of the traverse feed, and with the velocity of the cutting. Measurements were taken under two hundred and forty different conditions, either of cutting speed, depth of cut, or amount of traverse. One hundred and twelve of these experiments were made on cast iron, sixty-four on forged steel and sixty-four on bar iron.

For the cast iron two tools were used, the first tool having proved to be tempered too soft. The second tool was ground exactly to the same shape as the first, but was hardened in salt water; it lasted well, not requiring to be re-sharpened throughout the sixty-four experiments for which it was used. Nearly all the rake was put on the side of the tool, which was shaped with a round nose, suitable for a moderately heavy cut. The cutting face was ground so as to give an angle of 24° for top rake.

For the wrought-iron and the steel, one tool was used throughout the one-hundred-and-twenty-eight experiments. Nearly all its rake was on the side, being $46\frac{1}{2}°$ and the edge being round-nosed. This tool was hardened by quenching in water in which salt and wheaten flour were mixed. It was used without any tempering, and did not require any sharpening throughout one hundred and twelve experiments, in each of which it cut a shaving from an average diameter of two-an

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three-eighths inches, with a traverse of about one-and-a-quarter inches. Its edge slightly broke at the one hundred and thirteenth experiment in taking a cut, ·14 inches ($\frac{9}{64}$) deep on wrought iron of inferior quality with a good deal of dirt in its texture. The tool, after re-grinding to the same shape lasted well for the remaining sixteen experiments, cutting the same depth on the same material.

The cast iron experimented upon was of good soft quality, the diameters cut were sixteen and five-eighths inches, seven inches, and three-and-a-quarter inches, and the difference in diameter was judged to make little or no difference in the force required for cutting, other conditions being the same. The steel used was a tough forging two and five-eighths inches diameter. The wrought iron was common bar of inferior quality two-and-a-quarter inches diameter. All the cuts were taken without any lubricant being applied to the tool, and the tool was carefully kept in same position throughout.

One of Smith and Coventry's swivel tool-holders was used, it had a five-sixteenths inch hole drilled through its shank parallel to the axis of the work at a short distance from its front end. A cradle of wrought iron was made to take the holder, so that it was secured sideways but free to move on the pin through a short vertical arc. The cradle was bolted on the tool-plate of a back-geared lathe fourteen-and-a-half inches centre. The vertical motion of the tool-holder was limited by the spaces above and below. These were filled by small steel feeler-plates, which together, just prevented any motion of the shank, but which could themselves be moved so as to feel what pressure was confining them. The shank of the tool-holder was prolonged by firmly bolting to it a long bar of iron, graduated like a scale-beam and fitted with heavy and light weights, by means of these the pressure on the tool could be accurately balanced. An arrangement was made for putting

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the whole apparatus in equilibrium after the tool was in position and before either weight was attached. The feeling pieces showed with great delicacy, very slight variations in pressure.

On commencing an experimental cut, the pressure on the tool point would be counteracted by the top feeler-plate and this would be firmly wedged till the heavy weight was shifted along the bar to approximately balance the pressure. The small weight was then shifted to adjust the balance so as to give equal freedom to the two feeler-plates. The very heavy cuts caused so much tremor that the feeler-plates felt tighter than when the lathe was steady, but after a little practice it was always easy to set the weight so as to precisely equalise the pressure on each feeler-plate, when the cutting point sustained a pressure up to about 200 lbs., a difference of 2 lbs. was easily felt, up to 600 lbs. to 700 lbs. the possible error was not more than 3 lbs., and the greatest load used, 920 lbs., was gauged within 5 lbs.

Each cut was taken at four different speeds, ranging from the slowest speed of the lathe to the fastest at which it was capable of making the desired cut. As in some of the experiments the cuts taken were heavier than suited the lathe the highest speeds in these cases are below what would be practicable in a larger lathe under similar conditions of work. The speeds at which the metals were cut varied as follows :—

Cast iron,	from 14 feet to	$2\frac{1}{3}$	feet per minute.		
Wrought iron,	„ $9\frac{1}{3}$	„	$1\frac{1}{2}$	„	„
Steel,	„ 6	„	$1\frac{1}{3}$	„	„

In all cases the pressure was measured at each speed. The results showed that there is a very trifling increased force required for increased cutting speed. This slight increase is constant for all conditions of cutting for deep or shallow cuts, for broad or narrow feeds and for all the three metals experimented upon. The increase of force corresponding to

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the alteration from the slowest to the fastest speed averaged about 25 lbs. In one experiment it was as great as 40 lbs., and in two as small as 10 lbs.

The following examples illustrate the comparative resistance to cutting in the three metals experimented upon. In each case the feed traverse is the same, viz. ·0385 inches, a trifle over $\frac{1}{32}$ inch.

	Depth of cut	Cutting speed	Pressure on tool.
Cast iron,	·03 inches.	13·0 feet.	176 lbs.
	·05 „	12·7 „	252 „
Wrought iron,	·03 „	9·6 „	190 „
	·06 „	9·1 „	470 „
Steel,	·04 „	5·8 „	430 „
	·06 „	5·1 „	680 „

These figures show that forged steel takes from 2 to 2½ times the power required to cut cast iron, for both thin ($\frac{1}{32}$ inch) and moderately thick ($\frac{1}{16}$ inch) shavings. Wrought iron takes very little more power than cast iron for thin ($\frac{1}{32}$ inch) shavings, and rather more than one-and-a-half times the power for the thick. For broad thin shavings, it was found, that cast iron required more power than wrought. The rate of tool traverse causes a very decided variation in the pressure, as the following table shows.

	Traverse feed.	Pressure on tool.
Wrought iron: cutting speed 9·1 feet per minute.	·0303	435 lbs.
	·0385	470 „
	·0555	530 „
	·0606	570 „
Steel: cutting speed 5·1 feet per minute.	·0303	615 lbs.
	·0385	680 „
	·0555	705 „
	·0606	810 „

Depth of cut was ·06 inch, in all the above experiments.

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The figures published by Professor Smith do not afford such useful information as would have been available, had the experiments been conducted with systematic differences of speed, traverse and depth of cut. All these quantities are continually varying throughout the experiments, and there is no data to furnish means of calculating the most advantageous conditions, considering all the factors of speed, traverse and depth of cut. The three accompanying tables are arranged to show, as much as possible, concerning the results attained. Each table is complete in itself, as far as it goes, but there is a great want of more data.

TABLE I.—PRESSURE ON TOOL.

Traverse feed of Cutting Tool.	Cast Iron.		Wrought Iron.			Steel.		
	in. ·05 ft. 12·7	in. ·135 ft. 11·1	in. ·03 ft. 9·6	in. ·06 ft. 9·1	in. ·14 ft. 7·9	in. ·02 ft. 6·	in. ·04 ft. 5·8	in. ·06 ft. 5·1
	Pressure on the cutting edge, in pounds.							
·0303	228	510	165	435	630	185	365	615
·0385	252	620	190	470	760	215	430	680
·0555	288	690	215	530	810	250	480	705
·0606	340	775	250	570	920	315	665	810

The first horizontal line of figures show the depth of cut in decimals of an inch, and the second line of figures show the surface velocity in feet, per minute, in each series of experiments. The first vertical column shows the traverse feed of the tool in decimals of an inch. The remaining figures show the pressure, in pounds, on the cutting edge of the tool under the various depths of cuts and rates of velocity given in the first two horizontal lines.

The table of cutting forces show what pressure is exerted on

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the point of the tool, and, by this table may be noted the effect of varying the traverse feed. The top horizontal line shows the pressure exerted in cutting a shaving ·0303 inch wide, and the bottom line shows the pressure when the width is doubled. In every case the pressure is increased proportionately less than the feed, so that coarse feeds are evidently economical. The figures available do not, however, afford any indication of the effect of increasing the feed beyond ·0606 inches till the limit of economy of coarse feeds is passed. In each case, when the depth of cut has been altered, the rate of speed has also been altered so there is no indication as to the relative economy of either simply altering the depth of cut, or of altering the speed of the work.

TABLE II.—QUANTITY OF METAL REMOVED.

Traverse feed of Cutting Tool.	Cast Iron.		Wrought Iron.			Steel.		
	in. ·05 152·5	in. ·135 133·25	in. ·03 115·25	in. ·06 109.25	in. ·14 95	in. ·02 72	in. ·04 69·75	in. ·06 61·25
	Quantity of Metal removed, as Shavings, in cubic inches.							
·0303	138.6	327·0	62·8	119·2	241·7	26·2	50·7	66·8
·0385	176·1	415·5	79·8	151·4	307·2	33·2	64·4	81·3
·0555	253·9	598·4	115·1	218·3	442·8	47·9	92·9	122·7
·0606	277·2	654·0	125·7	238·3	483·6	52·4	101·4	133·6

The first horizontal line of figures show the depth of cut in decimals of an inch, and the second line of figures show the surface velocity in inches, per minute, in each series of experiments. The first vertical column shows the traverse feed of the tool in decimals of an inch. The remaining figures show the quantity of metal removed, as shavings in cubic inches, under the various depths of cuts and rates of velocity given in the first two horizontal lines.

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The next table shows the quantity of metal removed as shavings, as the result of ten hours' work, calculated from the data in the previous table. As the speed differs in every case where the depth of the cut differs, satisfactory comparisons are difficult to make.

TABLE III.—QUANTITY OF METAL REMOVED PER UNIT OF PRESSURE.

Traverse feed of Cutting Tool.	Cast Iron.		Wrought Iron.			Steel.		
	in. ·05 152·5	in. ·135 133·25	in. ·03 115·25	in. ·06 109·25	in. ·14 95	in. ·02 72	in. ·04 69·75	in. ·06 61·25
	Quantity of Metal removed per lb. pressure, cubic inches.							
·0303	·608	·641	·380	·274	·352	·142	·139	·108
·0385	·698	·686	·420	·322	·404	·154	·150	·119
·0555	·881	·867	·535	·412	·546	·191	·194	·159
·0606	·815	·844	·500	·403	·526	·166	·167	·140

The first horizontal line of figures show the depth of cut in decimals of an inch, and the second line of figures show the surface velocity in inches, per minute, in each series of experiments. The first vertical column shows the traverse feed of the tool in decimals of an inch. The remaining figures show the quantity of metal removed, per pound pressure, in cubic inches, under the various depths of cuts and rates of velocity given in the first two horizontal lines.

The economy of wear and tear in the execution of a given quantity of work may be seen in the next table, where the quantity of metal removed for each unit of pressure on the tool's edge is shown is thousandths of a cubic inch. By this may be seen that the results shown by the thirty-two experiments in Table III. are as follows :—

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Of 8 in. cast iron, the 3rd was most economical, the 1st least.
„ 12 „ wrought iron, 11th „ „ 5th „
„ 12 „ steel, 7th „ „ 9th „

These figures should prove interesting to metal turners and will, I hope, lead some of my readers to make further experiments of which I shall be glad to hear.

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